The 3rd National Forest Inventory Survey in Lao People's Democratic Republic

September 2019

Department of Forestry, Ministry of Agriculture and Forestry, Lao PDR

Sustainable Forest Management and REDD+ Support Project (F-REDD), JICA

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Acronyms

Acronym	Name
ADB	Asian Development Bank
AGB	Above Ground Biomass
BGB	Below Ground Biomass
CF	Coniferous Forest
CI	Confidence Interval
CliPAD	Climate Protection through Avoided Deforestation
DBH	Diameter at Breast Height
DD	Dry Dipterocarps Forest
DOF	Department of Forestry
DOFI	Department of Forestry Inspection
DW	Dead Wood
EF	Emission Factor
EG	Evergreen Forest
FCPF CF	Forest Carbon Partnership Facility Carbon Fund
FIM	Forest Information Management Project
FIPD	Forest Inventory and Planning Division
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
F-REDD	Sustainable Forest Management and REDD+ Support Project in the LAO PDR
GIS	Geographic Information System
GiZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Corporation for International Cooperation)
GPS	Global Positioning System
IPCC	Intergovernmental Panel on Climate Change
ITPP	Industrial Tree Plantation Project
JICA	Japan International Cooperation Agency
JICS	Japan International Cooperation System
KfW	Kreditanstalt für Wiederaufbau (a German state-owned development bank)
Lao PDR	The Lao People's Democratic Republic
MAF	Ministry of Agriculture and Forestry
MCB	Mixed Coniferous and Broadleaved Forest
MD	Mixed Deciduous Forest
NAFES	National Agriculture and Forestry Extension Service
NAFRI	National Agriculture and Forestry Research Institute
NFI	National Forest Inventory
NFIS	Capacity Development Project for Establishing National Forest Information System for Sustainable Forest Management and REDD+
NTFP	Non Timber Forest Products
NTV	Non Tree Vegetation
PAFO	Provincial Agriculture and Forestry Office
PAREDD	Participatory Land and Forest Management Project for Reducing Deforestation in Lao PDR

PKK NPA	Phou Khao Kouay National Protected Area
PSUs	Primary Sampling Units
QC	Quality Control
REDD+	Reducing Emissions from Deforestation and Forest Degradation and the role of conservation of forests and enhancement of forest carbon stock
StD	Standard Deviation
StE	Standard Error
SOP	Standard Operating Procedure
SSUs	Secondary Sampling Units
SUFORD	Sustainable Forest Development Project
UNFCCC	United Nations Framework Convention on Climate Change

1. Introduction

1.1 Background

In Lao PDR, various field survey of forests in the country have taken place in the past (Table 1) including what is regarded as the country's first National Forest Inventory (1st NFI) conducted in 1991-1999. The primary objective of the 1st NFI was standing timber volume estimation.

Triggered by Lao PDR's participation in the Reducing Emissions from Deforestation and Forest Degradation – Plus (REDD+) initiative under the UN Framework Convention on Climate Change (UNFCCC), a second NFI (2nd NFI) was considered necessary, and commissioned by the Government, and implemented by the Forest Inventory and Planning Division (FIPD) of the Department of Forestry (DOF) within the Ministry of Agriculture and Forestry (MAF). Technical and financial support was provided from Japan International Cooperation Agency (JICA). Lao PDR submitted its initial Forest Reference Emission Level / Forest Reference Level (FREL/FRL) for REDD+ to the UNFCCC in January 2018 (and the modified submission in October 2018) using data from the 2nd NFI. Subsequently, the UNFCCC technical assessment was completed in January 2019[1].

Following the completion of the FREL/FRL, Lao PDR conducted the estimation of the 1st National REDD+ Results in 2020. As a part of the 1st National REDD+ Results estimation process, the third NFI (3rd NFI) was conducted to update the Emission and Removal Factors. This report summarizes the objectives, methods and results of the 3rd NFI conducted from January to April 2019.

Table 1: Brief summary of forest inventories conducted in Lao PDR

Survey name	Main objective	Survey period	Surveyed area (provinces)	Implementing Agencies	Supporting projects / donors
National level					
1st NFI	Timber volume estimation	1991-1999	Entire country	DOF/FIPD	Sweden
2nd NFI	Biomass stock measurement, Non Timber Forest Product	2015-2017	Entire country	DOF/FIPD DFRM	Forest and Forest Resource Development Fund, JICA, FCPF Readiness
3rd NFI	Biomass stock measurement, Non Timber Forest Product	2019	Entire country	DOF/FIPD	JICA, FCPF Readiness
Project-based data with tree biomass information (not used in the estimation of 1st National REDD+ Results)					
SUFORD (Phase 1-3)	Timber volume estimation	2003-2017	Khammouane, Savannakhet, Salavanh, Champasack, Xekong, Attapeu,	DOF, DOFI, NAFES, NAFRI, PAFO, DAFOs, VFUs	Worldbank, Finland

[1] Available at <https://redd.unfccc.int/submissions.html?country=lao>.

			Bolikhamxay, Vientiane, Xayabouly		
Industrial Tree Plantation Project (ITPP)	Timber volume estimation	2006	Bolikhamxay, Champasack Salavanh, Savannakhet, Vientiane	ITPP	ADB
CliPAD	Biomass stock measurement	2009-2018	Xayabouly Houaphanhh	MAF, DoF, PAFO, DAFO	GiZ, KfW
PAREDD	Biomass stock measurement	2009-2014	Luang Prabang	NAFES, PAFO, DAFO	JICA
FIM	Biomass stock measurement	2010-2013	Entire country	DOF/FIPD	JICS
Allocated the Forest/Land for fruit tree garden and livestock	Timber volume estimation	2017	Khammouane	DOF/FIPD	Soukhounghueng Co., LTD
Pre-harvesting and Transect survey at Nambee dam 1, 2, 2&3.	Timber volume estimation	2018	Xekong	DOF/FIPD	Nambee Power co., LTD
Pre-harvesting and Transect 230 KW of Xekong 2 and Xekhaman 2 dam.	Timber volume estimation	2018	Xekong	DOF/FIPD	Electicite du Laos
Pre-harvesting survey at Houayemoon dam	Timber volume estimation	2018	Xekong	DOF/FIPD	Chalern Xekong Power Co., LTD
Pre-harvesting survey at Xekong 4A and 4B dam	Timber volume estimation	2018	Xekong	DOF/FIPD	Lao-Vern Construction and Road Co.,LTD
Pre-harvesting survey at Houaylange dam	Timber volume estimation	2018	Xekong	DOF/FIPD	Chientho Investment Co.,LTD
Pre-harvesting	Timber volume estimation	2018	Xekong	DOF/FIPD	Attapue Commerce

survey at Xekong 5 dam					Import and Export State Enterprise Co.,LTD
Pre-harvesting survey at Namkhong 3 and Namang dam	Timber volume estimation	2018	Attapue	DOF/FIPD	Chalern Xekong Power Co., LTD. Chalern Xekong Power Co., LTD
Allocated the Forest/Land and Pre-harvesting for mining	Timber volume estimation	2018	Vientiane Province, Bolikhamxay	DOF/FIPD	Khongchay SYHALATH Mining Co., LTD. Kavigo Laos Mining Co.,LTD
Pre-harvesting and Transect survey at Namhong Dam	Timber volume estimation	2018	Bolikhamxay	DOF/FIPD	Khoungtoung Co.,LTD
Tree Plantation Project	Allocated the Forest/Land for Tree Plantation	2019	Bolikhamxay, Vientiane Province, Khammouan	DOF/FIPD	Boualapha Agriculture and Forestry Co., LTD. Strola-An Co.,LTD
Livestock Project	Allocated the Forest/Land for Livestock.	2019	Xiengkhoung	DOF/FIPD	Agriculture Development Lao-Japan Co., LTD

1.2 Objectives of the 3rd NFI

The objectives of the 3rd NFI was to survey the forest biomass to estimate forest carbon stock[2] of the five natural forest classes of Evergreen forest, Mixed Deciduous forest, Dry Dipterocarp forest, Coniferous forest, and Mixed Conifer and Broadleaf forests, for the scale of the entire national territory. The 3rd NFI results would then be used to estimate results of REDD+ as measured against the National FREL/FRL, which was developed based on the 2nd NFI of 2015-2017.

The scope of the 3rd NFI were limited to natural forest classes, and excluded forest plantations, due to the relatively small expanse and availability of applicable IPCC default factors for biomass estimation for the purpose of REDD+ results estimation. Bamboo[3]and Regenerating Vegetation[4] classes which fall outside the national forest definition of "current forest" (stand DBH: minimum of 10cm, crown density: minimum of 20%, area: minimum

[2] The main target of the survey was to measure the forest carbon, however, other information, such as observed disturbances and NTFP (Non-Timber Forest Products) were also recorded.
[3] Although Bamboo is measured as one of the components of the AGB for the surveyed forest classes.
[4] The biomass of Regenerating Vegetation was separately surveyed in the "2nd RV Survey". See DOF, et al. (2019). Update survey of a Lao specific biomass prediction model for regenerating vegetation and confirmation of the threshold number of years since abandonment, as Regenerating Vegetation, before becoming current forest.

of 0.5ha) were also excluded.

The 3rd NFI was conducted by following the Standard Operation Procedures (SOP)[5] Manual for Terrestrial Carbon Measurement which was updated after the 2nd NFI. The updated SOP essentially improves the previous SOP without changes to the underlying technical methodology.

The 3rd NFI involved also a Quality Control (QC) survey conducted by a separate team of more experienced FIPD staff to re-measure more than 10% of the total number of survey plots (i.e. 47 plots out of the total 415 plots). The QC survey plots were distributed to secure a minimum 10% for each forest class at the national-level. The QC survey followed the same methods with the main survey.

[5] The original version was developed by "Capacity Development Project for Establishing National Forest Information System for Sustainable Forest Management and REDD+ (NFIS)" funded by JICA. The manual was modified as *Lao PDR National Forest Inventory Standard Operating Procedures (SOP) Manual for Terrestrial Carbon Measurement* and used for the 2nd NFI, and further updated before the implementation of the 3rd NFI.

2. Preparation

2.1 Determining the number of survey plots

Following the SOP, the number of survey plots for the 3rd NFI (excluding the QC survey) were determined based on parameters of 'mean', 'standard deviation' and 'target precision' for each of the five forest classes. The 'mean' and 'standard deviation' of each forest class was derived from the 2nd NFI data, while the 'target precision', was based on the expert judgement of FIPD and international experts after examining the existing data. The number of survey plots was calculated by applying the following equation[6] with a minimum sample size of 30 plots per forest class.

$$number\ of\ plots\ for\ strata = (z * \frac{standard\ deviation}{\mathrm{t} * x})\text{^}2$$

Where:

z= score for the required confidence interval
t = level of error
x= the mean estimated biomass value of a strata (t dry matter ha-1)

The preliminary survey plot numbers identified for each forest class are in Table 2.

Table 2 : Preliminary target numbers of survey plots per forest class for the 3rd NFI

Forest class	Preliminary plot numbers (n)	Target precision
Evergreen forest (EG)	38	<10% Error at 90% CI
Mixed Deciduous forest (MD)	49	<10% Error at 90% CI
Dry Dipterocarp forest (DD)	64	<10% Error at 90% CI
Coniferous forest (CF)	30	<20% Error at 90% CI
Mixed Conifer & Broadleaf forest (MCB)	47	<20% Error at 90% CI
Total	228	

In the 2nd NFI, the target number of plots (determined based on parameters of 'mean', 'standard deviation' and 'target precision') were equal to the number of preliminary plot (actual number of plots planned for field survey) for each forest class. However, through the field survey, the minimum target number (30 plots) was not achieved for the EG and CF classes (Table 3). The 'map - field rate' (number of plots identified in the field divided by the number of preliminary plots for each forest class) shows the lowest for EG = 24.2%, followed by CF = 48.0%. One reason for the low rates in these classes is because the preliminary plots were distributed based on the forest classes of Forest Type Map 2015, whereas in some cases, the actual forest classes on the ground were identified

[6] Winrock International, sample plot calculator (Excel), <https://www.winrock.org/document/winrock-sample-plot-calculator-spreadsheet-tool/>.

as different from that of the Forest Type Map 2015. On the other hand, 45 plots were identified as MCB, despite the preliminary plot number allocated for this class being 30.

Table 3: Map-field rate in the 2nd NFI

Forest class	Preliminary plot numbers (n)	Plot numbers identified in field (n)	Map-field rate (%)
Evergreen forest (EG)	95	23	24.2
Mixed Deciduous forest (MD)	264	227	86.0
Dry Dipterocarp forest (DD)	120	101	84.2
Coniferous forest (CF)	50	24	48.0
Mixed Conifer & Broadleaf forest (MCB)	30	45	150.0
Total	559	420	-

From this experience, the map-field rates from the 2nd NFI were reflected into deciding the preliminary plot numbers for the 3rd NFI to ensure enough number of survey plots will be actually surveyed. To come up with the final plot numbers, the preliminary plot numbers were divided by the map-field rates and rounded-up to the nearest 10, as shown in Table 4 below. For example, the final plot number for EG plots were calculated as 160 (38 / 0.242 = 157 and rounded-up to 160). However, for MCB, where the map-field rate is over 100%, indicating that the final plot number will likely exceed the preliminary plot number, the preliminary plot number of 47, rounded-up to 50 as the final point numbers was applied.

Table 4: Final number of survey plots in the 3rd NFI

Forest class	Preliminary plot numbers (n)	Final plot numbers (n)
Evergreen forest (EG)	38	160
Mixed Deciduous forest (MD)	49	60
Dry Dipterocarp forest (DD)	64	80
Coniferous forest (CF)	30	65
Mixed Conifer & Broadleaf forest (MCB)	47	50
Total	228	415

2.2 Distribution of survey plots

Following the SOP, the sampling design started from selecting the primary sampling units (PSUs) and then the secondary sampling units (SSUs). This approach ensures that any location has an equal probability of being sampled. The PSUs were chosen by applying stratified-random-sampling approach. Grid cells were placed across the areas to be sampled in a randomly selected orientation. The grid cells will then serve as the 'primary sampling unit' (PSUs). Once the PSUs are chosen, a particular location within the PSU is randomly chosen as the secondary sampling unit (referred to in the figure below as "SSU1") then the field sampling is initiated.

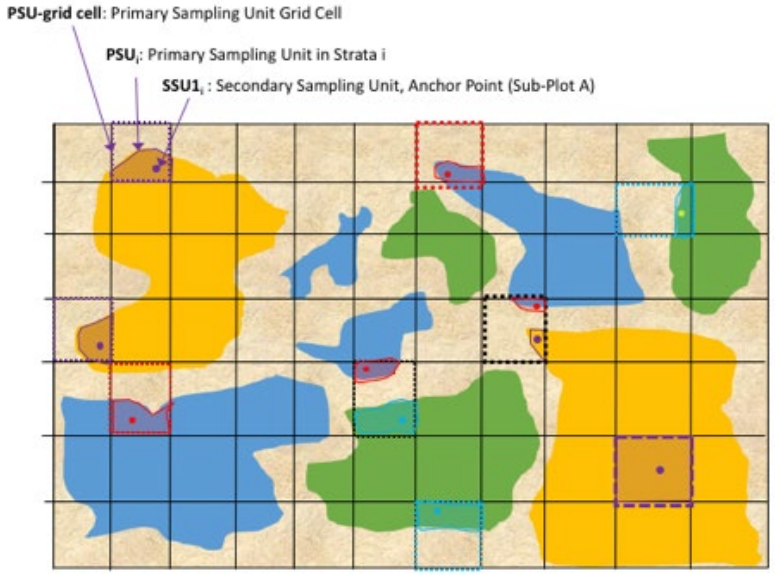


Figure 1: Example of selected PSU-grids in dashed lines and selected PSUs (polygons) with SSUs (dots) assigned within. Note some PSU-grids may randomly be selected for two different forest classes.

The survey plots were distributed to each forest class based on Forest Type Map 2015 (Figure 2). The detailed information of the surveyed plots are presented in Annex 3.

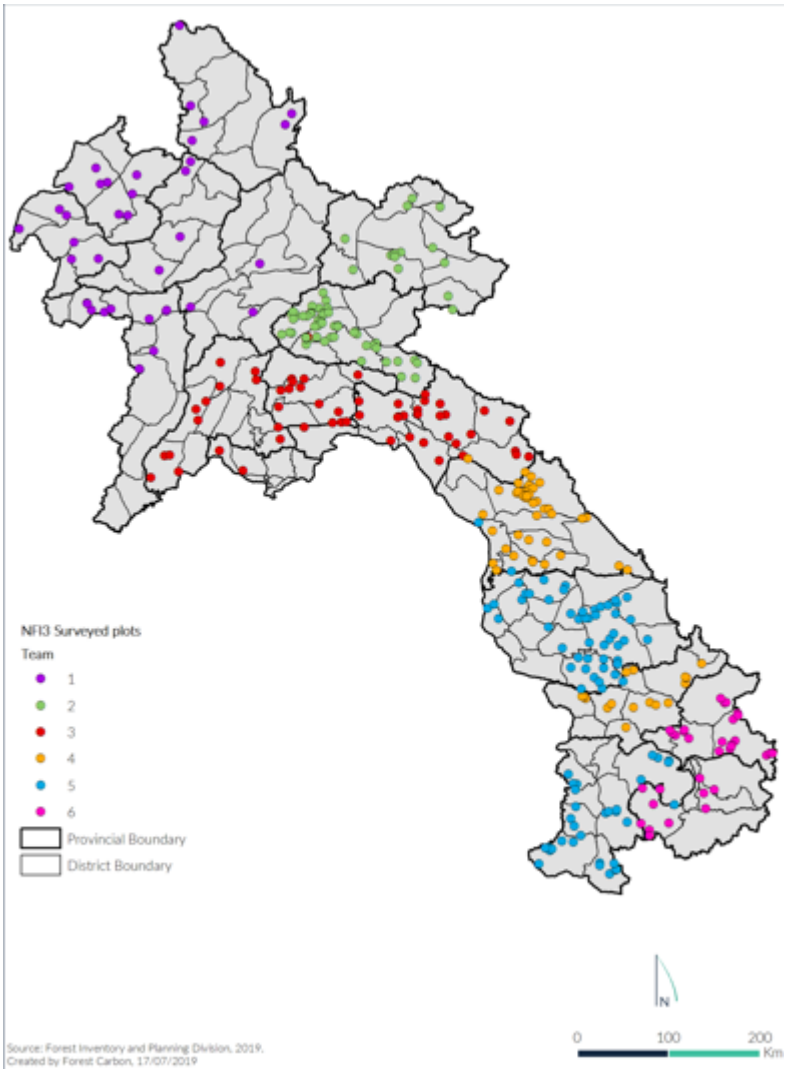


Figure 2: Map of surveyed plots – color coded by survey teams

2.3 Obtaining permission and list of equipment for the survey

A proposal for the 3rd NFI was prepared by FIPD and submitted to DOF for approval. The proposal included information related to the purpose of the survey, survey site (province), survey team members and budget. Then, FIPD sent request letters to PAFO and DAFO of each province with the DOF approval letter, to request for their support in the survey implementation. This process took three weeks.

A summary list of the equipment used for the survey is shown in Annex 2.

2.4 Cost for 3rd NFI

The total cost for the 3rd NFI, which include per diems, accommodation and transportation fees for the survey teams, equipment and miscellaneous costs was approximately USD 250,000. This cost was shared among projects including F-REDD funded by JICA[7] and FCPF Readiness Project (RP).

2.5 Training and field work supervision

Trainings consisting of four components were conducted mainly for FIPD staff.

1. **Field survey training**: Before starting the field surveys, trainings were provided to the survey teams as well as the QC team. The trainings were conducted in late October and early November 2018.

i) **Classroom training**: The two-day training aimed at familiarizing the NFI field teams with the revised SOPs, and introducing them to the latest additions to the ODK tablet form and OruxMaps. The training also included sessions on forest class identification in the field considering current Lao definitions of forest class as well as a risk assessment to sensitize the teams to the inherent hazards associated with survey work and discuss appropriate mitigation actions to lower these risks. A first aid training was also provided by the Vientiane Rescue association to ensure the teams had basic response skills in case bodily injury or harm occurred when conducting the field inventory.

Two additional days of classroom training were conducted in late December and early January to first address issues exposed by the field training and secondly to re-familiarize the teams with the SOP just before departing for the survey after the two months delay.

ii) **Field-based training**: the field based training was conducted in Phou Khao Kouay National Protected Area (PKK NPA) in early November 2018. The training took three days and included: (i) a day with all the field teams reviewing the SOP process in a single sub-plot location; (ii) a full day where two field teams combined forces to navigate to and then inventory two sub-plots together; and (iii) a full day where each field team navigated to and inventoried a minimum of four sub-plots that comprise a full plot. The QC team was asked to re-survey one plot surveyed just before by one team and found the exact center of each sub-plot indicated by the metal bar.

2. **Remote Sensing & GIS training**: the three days training, conducted in January 2019, introduced the various steps to distribute the survey plots;

- Calculate number of required plots by strata (forest classes): Use the Winrock Sample Plot Calculator Excel spreadsheet to enter the known carbon stock values from previous the NFI along with the targeted uncertainty level to get the required number of plots.

- PSU plotting in ArcGIS: Combine the various forest class geographical layers with the 3 kilometers square grid and the steep areas.

[7] Excluding the costs of F-REDD experts who technically supported the 3rd NFI.

- PSU selection: Conduct the first random sampling stage in Excel and select as many PSUs as required per strata.
- Sub-plots distribution: Conduct the second random stage sampling in ArcGIS using ModelBuilder. This step randomly locates the anchor plots and distributes the sub-plots within a 300 meters radius.
- Remote sensing based check to validate if the sub-plots fall into forested areas.
- Labelling plots in ArcGIS: Assign a unique identifier to the sub-plots with a number and a letter.
- Export to GPS and OruxMaps: Convert the shapefile into GPX and POI (Point Of Interest) for the GPS unit and KML for the tablet.

3. **QC team field oversight**: The QC team was accompanied by the sub-contractor hired under F-REDD during its first week of their QC field survey in February 2019 in Xaysomboun province to make sure the QC team properly follows the requirements of QC activity as well as the SOP for re-measuring the plots.

4. **Carbon stock calculation training**: a five day training was conducted in early June 2019 at the FIPD offices. It was designed specifically for the FIPD staff from the Data Processing and Forest Planning Section. Additionally, three staff from the REDD+ Office joined the training. The training aimed to guide the technicians through all the steps required to calculate the carbon stocks of the various forest classes using Excel, from the raw data aggregated in ONA.

3. Survey method[8]

3.1 Target carbon pool

In the National FREL/FRL[9], only aboveground biomass (AGB) and belowground biomass (BGB) were considered as significant carbon pools, based on the forest classes surveyed under the 2nd NFI (summarized in **Table 5**). From here, the target carbon pool in the 3rd NFI was reconsidered and insignificant components were excluded from survey items of the 3rd NFI for best cost performance.

Table 5: 2nd NFI carbon stock of all forest classes

Carbon pool and components	Carbon stock (tC/ha)	% of each components
Aboveground Biomass (AGB)	**70.66**	**75.46**
Living tree	67.68	72.27
Sapling	0.54	0.58
Non-Timber Vegetation (NTV)	1.71	1.82
Bamboo	0.76	0.81
Belowground Biomass (BGB)	**15.66**	**16.72**
Dead Wood (DW)	**7.32**	**7.82**
Standing Dead Wood	5.07	5.42
Stump	0.26	0.28
Lying Dead Wood	1.99	2.12
Total	**93.64**	**100.00**

Although Deadwood (DW) is not regarded as a significant carbon pool in the National FREL/FRL and therefore not to be accounted in the 1st National REDD+ Results, two of its sub-components were measured in the 3rd NFI due to the following reasons:

- Standing Dead Wood: this accounted for a relatively large portion of the total carbon stock (5.42%) in the 2nd NFI, and is considered useful for potential use in the future.
- Stump: this is not a significant carbon pool. However, it was necessary to repeat the measurement in order to estimate carbon loss from selective logging accounted for in the National FREL/FRL.
- Lying Dead Wood: this is not a significant carbon pool therefore omitted from the measurement.

The 2nd NFI result showed that the sub-components of AGB carbon pool besides living tree, were very small (Table 5). Usually those carbon pools do not change drastically within two years (i.e. years from the 2nd NFI to the 3rd NFI), thus excluded from the survey items of the 3rd NFI. For Sapling, Non-Timber Vegetation (NTV) and Bamboo, the result of the 2nd NFI were used for estimating the carbon stock.

[8] The detail methods and procedures are described in "Lao PDR National Forest Inventory Standard Operating Procedures (SOP) Manual for Terrestrial Carbon Measurement".
[9] https://redd.unfccc.int/submissions.html?country=lao

Table 6 summarizes the surveyed carbon pools under the 2nd and 3rd NFIs.

Table 6: Surveyed carbon pools in 2nd and 3rd NFIs

Measurement items	2nd NFI	3rd NFI
Aboveground Biomass (AGB)		
Living tree	Measured	Measured
Sapling	Measured	Used 2nd NFI data
Non-Timber Vegetation (NTV)	Measured	Used 2nd NFI data
Bamboo	Measured	Used 2nd NFI data
Belowground Biomass (BGB)	Used IPCC defaults	Used IPCC defaults
Deadwood (DW)		
Standing Dead Wood	Measured	Measured
Stump	Measured	Measured
Lying Dead Wood	Measured	Used 2nd NFI data
Litter (not included as a carbon pool)	Not measured	Not measured
Soil (not includes as a carbon pool)	Not measured	Not measured

3.2 Establishment of plots

In the 'floating' clustered plot design, measurements at each sampling point takes place only when the sub-plot falls under a natural forest class. The locations of the plot anchor point and the sub-plots are determined prior to field sampling and in a GIS environment. Due to the highly fragmented landscape and difficult terrain requiring considerable time to access some plots, a desk based pre-assessment was conducted using high resolution imagery (Sentinel-2 mosaic 2018) to increase the probability that sampling locations contain the target forest type and have reasonable access routes.

Using GIS, for a given stratum the cluster plot anchor point (i.e., sub-plot A) was placed and then up to nine additional points (B, C, D, E,…, J) are then randomly placed in GIS within the given stratum within a 300 m radius of the cluster plot anchor point, but no closer than 75 m from the nearest point between each sub-plot or the cluster plot anchor point. A single cluster must contain at least six potential sub-plots to allow the field teams to measure four valid sub-plots.

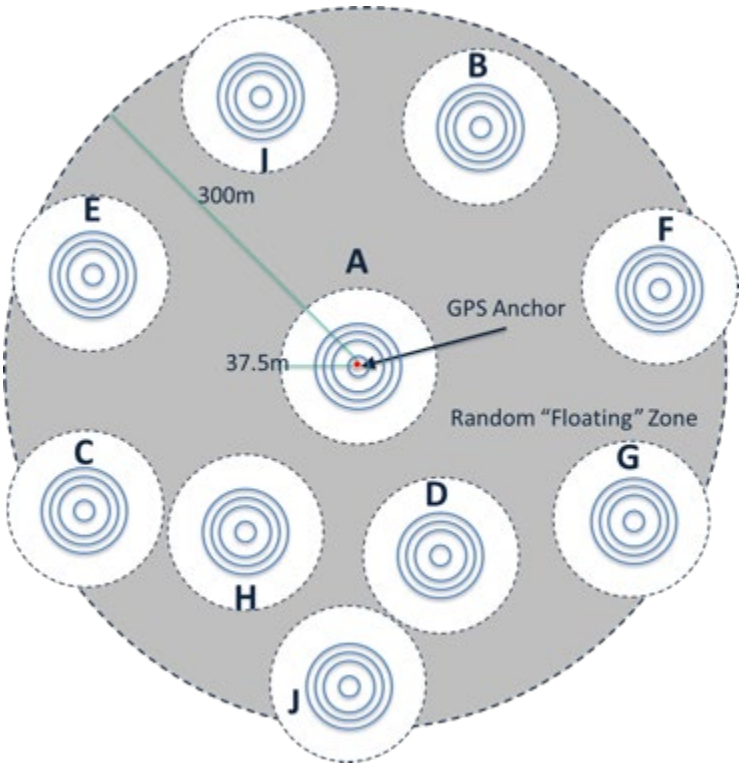


Figure 3: A "floating" cluster plot with a fixed center subplot

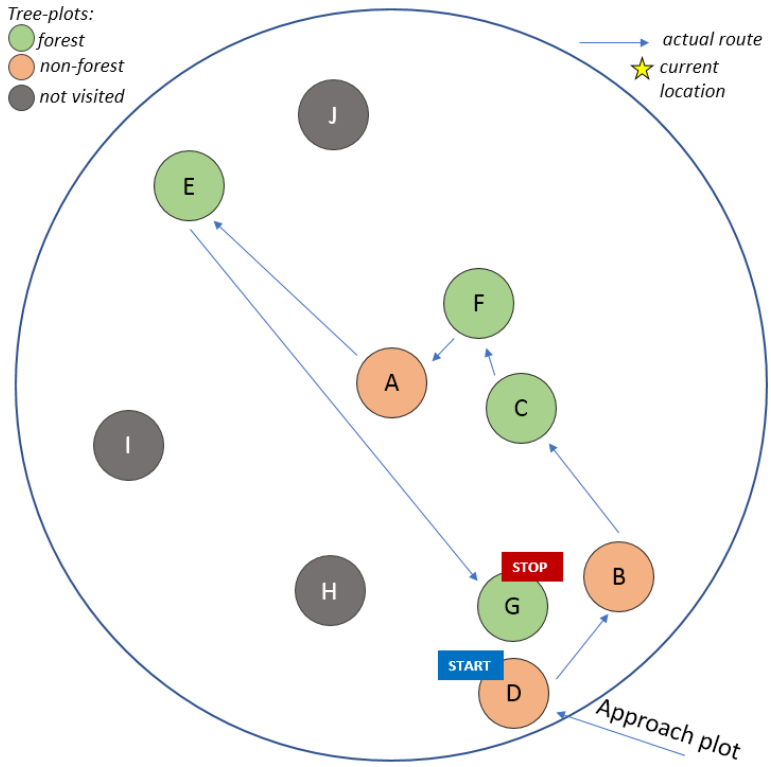
In the 2nd NFI experience, allocating an even number of sub-plots per cluster resulted in many cluster plot results being invalid, because the forest classes identified were split evenly among the surveyed sub-plots, not rendering a single majority forest class for the cluster plot. For instance, a cluster plot may have two sub-plots identified as Mixed Deciduous forest (MD) and another two sub-plots identified as Evergreen forest (EG). In such a case, there is no single majority forest class for which the cluster plot could be assigned as, and therefore, unable to be used. To prevent this situation, in the 3rd NFI the teams were assigned to survey a minimum of four sub-plots in natural forests, of which at least three sub-plots are of the same forest class.

In the 2nd NFI experience, the sub-plot shifting options of 100 meters in four directions (north, east, south and west) in order to relocate a sub-plot center to contain forest cover, resulted in needing to traverse difficult terrain in four directions (for instance if no forest was found at the sub-plot center, the team would shift 100 meters towards the east, and the south, west and finally north if no forest was found at each subsequent shift). This was considered inefficient by the field teams. Consequently, the 3rd NFI plot design (Figure 3) was revised to include six to ten sub-plots per cluster plot to offer more potential locations for the team and avoid back and forth shifting.

3.3 Sub-plot Navigation

Considering the difficult terrains in much of the forested areas of the country, efficient navigation between sub-plots is important for conducting a time and therefore cost-efficient survey. In the 2nd NFI, survey teams were asked to start the survey from sub-plot A (see Figure 4), which is the anchor of the cluster plot, and then survey

in any order the remaining three other sub-plots by choosing the most efficient route. For the 3rd NFI, teams had to consider first the four sub-plots, A, B, C, D but could go in any order. If among those four sub-plots, one was not forest, the team would then consider the additional sub-plot (e.g. sub-plot F), but still could choose the best route and survey the sub-plots in any order. The same approach would apply in the case two where three or more sub-plots were non-forested, so the team would consider respectively to survey sub-plots, E, G, H, I and J. Figure 4 below illustrates an example of sub-plot navigation, along with the rationale explained in a table.



Order measured in field	Subplot ID	Valid subplot (is forest)?	Cumulative valid subplots at least = 4?	Order of field measurements has gaps?	Plot complete?
1st	D	No	No (0)	Yes	No
2nd	B	No	No (0)	Yes	No
3rd	C	Yes	No (1)	Yes	No
4th	F	Yes	No (2)	Yes	No
5th	A	No	No (2)	Yes	No
6th	E	Yes	No (3)	No	No
7th	G	Yes	Yes (4)	No	Yes

Subplots "**ABCDEFG**" were visited in the order:
D-B-C-F-A-E-G
A, B, D were in non-forest and **not measured**
C, E, F, G were in forest and **measured**
Subplots
H, I, J were not required and were not visited

Figure 4: Example of efficient plot navigation

3.4 Nested sub-plot design

Nested sub-plots

As with the 2nd NFI, a sub-plot consists of nested circles with different radius. In the 3rd NFI, sapling measurements were removed, therefore the 2 meters radius circle was omitted. For both living trees and standing dead wood, the nested circles remain unchanged. The Figure 5 below illustrates the 3rd NFI nested sub-plot design.

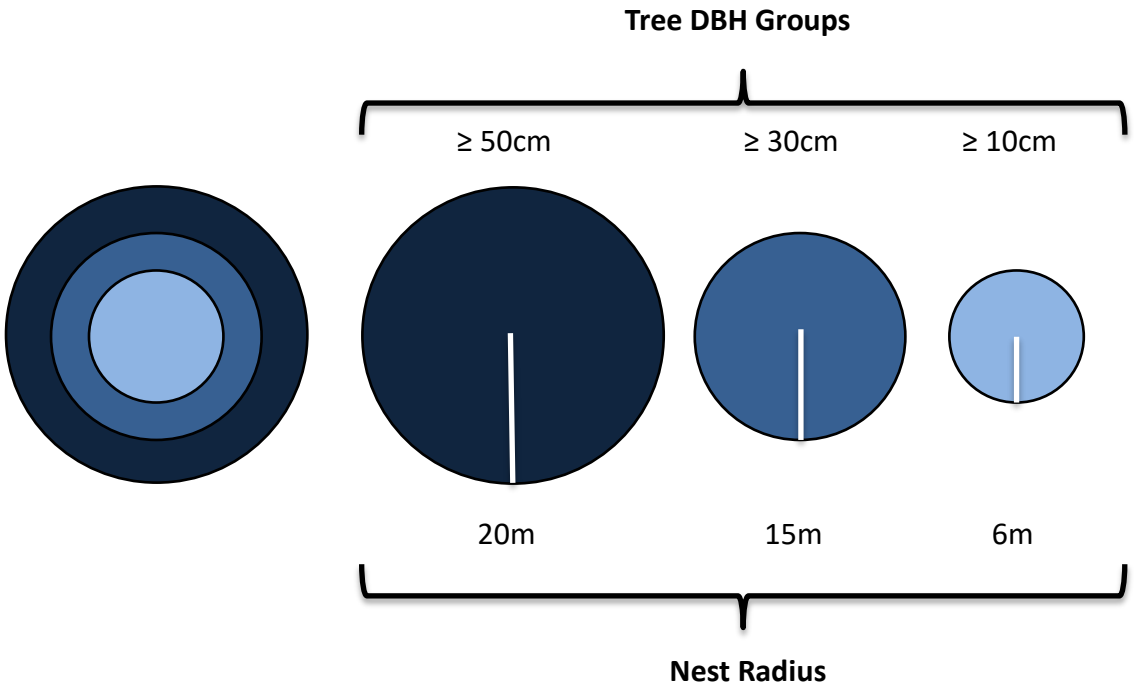


Figure 5: Nest radius of nested plots[10]

3.5 Field measurement

In the established sub-plots, only Living trees and standing Dead Wood including stumps were measured in the 3rd NFI.

Living trees

Record the species name and tree diameter at breast height (DBH 1.3m). Tree diameters should be measured to the nearest 0.1 cm (e.g. diameter of 10.2 cm *not* 10 cm).

Standing Dead Wood

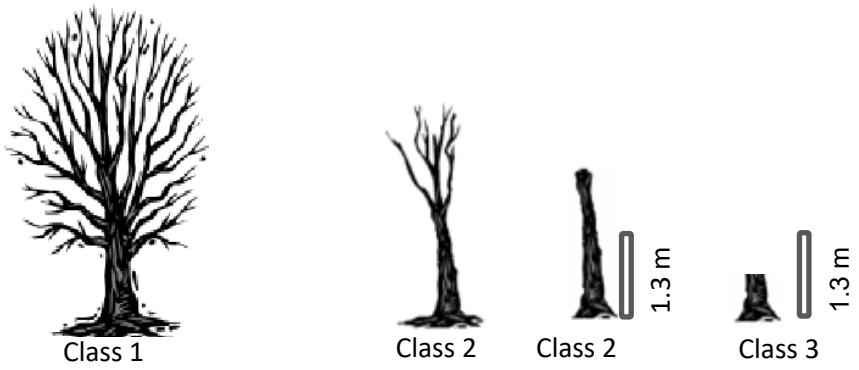
Standing Dead Woods were separated into three categories, i.e.: Class 1 - Dead Wood with twigs and branches, Class 2 -Dead Woods with large branches or no branches, and Class 3 - tree stumps. The three classes were measured with the following methods.

Class 1 Dead Wood: measure the trees using the same methods with living trees, and mark them as 'dead' on the datasheet.

[10] This is the design for a site condition when slope <10%. 'Tree DBH Groups" are the size classes of trees to be measured for each nest.

Class 2 Dead Wood: measure DBH using same methods for living trees. Measure the diameter at the base of the tree (Dbase). Measure height of stem (H) both using a clinometer and measuring tape or laser range finder or through direct measurement using tape measure. Measure diameter at top of the stump (Dtop,) through direct measurement. Alternatively, do not take a measurement at the top of the stump and write 'None' or 'NA' on datasheet.

Class 3 Dead Wood (stump): measure in all sub-plots. Three parameters were measured: height (H)[11], smallest diameter across the top of the stump (D_1) and diameter at 90° angle to (D_2).



3.6 Data entry, compilation and analysis

As the first step of the data entry and analysis process, the field measurement data were collected using the ODK form pre-installed in an android-based tablet computer. After all the measurement items at a survey cluster are collected, the data were entered into the form by the survey team and automatically sent to the ONA cloud-based server when the tablet comes into the range of 3G internet or Wi-Fi. All the data collected from the survey teams were aggregated at the server into a single CSV file and made available for downloading.

"NFI – Dash" is an application developed to support the data collection and analysis for the NFI[12]; its functions are shown in Figure 6 below. It allows the calculation of the results of and presents them graphically through easy-to-use interface. The NFI – Dash is a script based web application written in statistical program language "R" and the R Package "Shiny".

[11] Stumps with heights > 1.3m are considered as standing deadwood; class 2.

[12] The NFI – Dash has been, and will be continuously updated by incorporating new functions. For example, for this 3rd NFI, new information table and data-link were added to support the field survey.

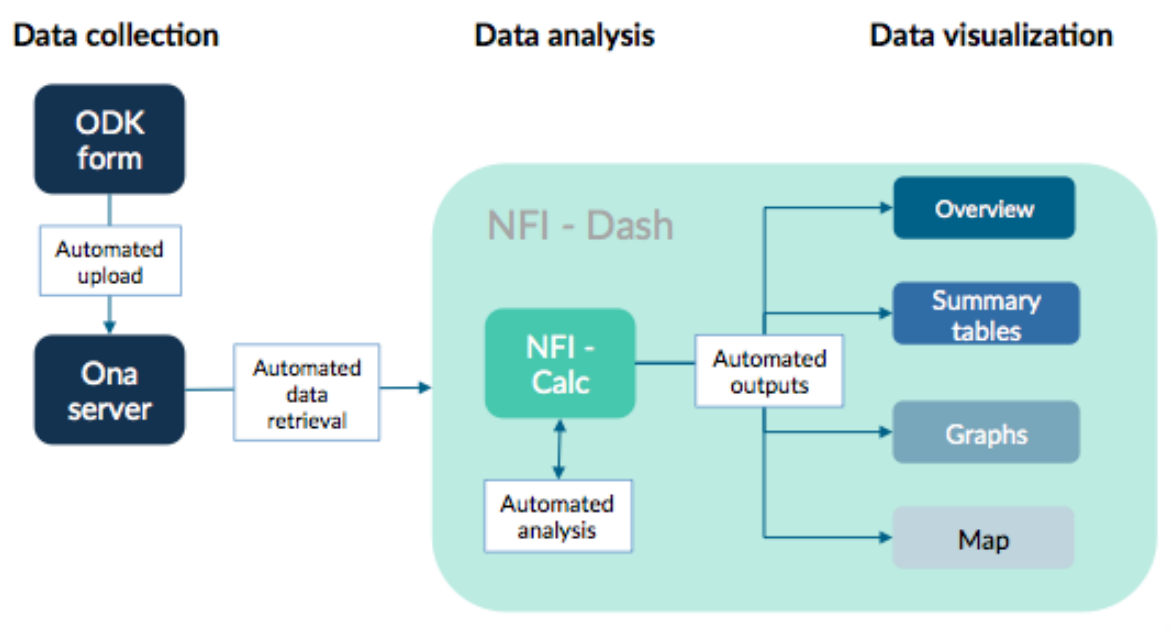


Figure 6 : Overview of the data collection and analysis process

When the NFI – Dash application is opened in a web-browser, it automatically retrieves the raw data from the Ona server, uses the script "NFI – Calc"[13] to preform various types of analysis and automatically generates a summary of the data collected to date. Two additional scripts ("NFI-Server" and "NFI-Interface") allow for developing various summary tables and graphs, and display the plot locations on a map.

[13] The "NFI – Calc" script is the backbone of the application and was developed and thoroughly tested during the NFI piloting phase in 2015, to ensure all possible quality issues were automatically flagged before moving to the full NFI implementation in 2016 and 2017. The first version of "NFI – Calc" during piloting stage essentially scripted the equivalent of all the calculations conducted in an excel spreadsheet that was used for the data analysis. Thus, each step of the "translation" process from excel to the script was verified by comparing the results of the script with the results of the spreadsheet.

4. Survey implementation

4.1 Implementation structure (team organization)

The field survey was conducted by 6 field survey teams. One field survey team was composed of members from FIPD, provincial and district level Agriculture and Forestry Offices, villagers, and drivers (Table 7). Each of the team leaders were selected from the FIPD staff who were involved in the 2nd NFI and experienced with field surveys.

Table 7: Survey team composition

Institution	Number of staff
FIPD (Forest Inventory and Planning Division)	3
Driver	2
PAFO (Provincial Agriculture and Forestry Office)	1
DAFO (District Agriculture and Forestry Office)	1
Villager	2

4.2 Survey schedule

The survey period was from January to April 2019. In fact, survey plans and trainings of the survey teams were completed in early November 2018, however, due to 2 months delay of the budget disbursement from the FCPF RP, the survey could only commence from early January 2019.

4.3 Monitoring

The web application "NFI – Dash" was used to monitor the progress and data quality through its web-based browser. Through frequent confirmation of the progress, the survey teams were able to survey the optimal number of survey cluster plots and sub-plots, which led to efficient delivery of the entire 3rd NFI.

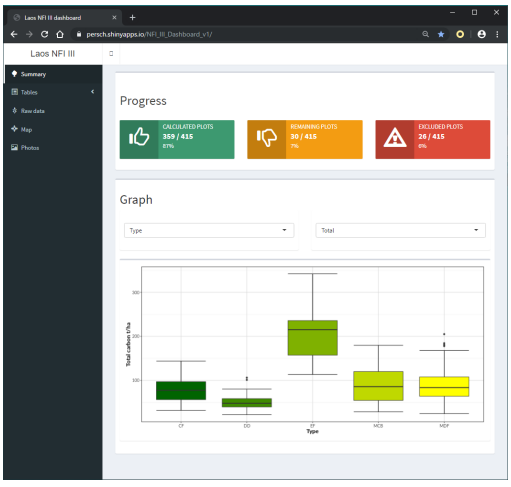


Figure 7: carbon stocks of each forest class shown in "NFI – Dash" web-application

5. Results

This chapter presents the analyzed results of the 3rd NFI including the QC survey results for the national level.

5.1 Carbon stocks at National Level

Forest class

Across the five forest classes surveyed, among the 415 plots distributed, a total of 359 plots were included in the estimation of forest carbon stocks. The remaining 61 plots were not included due to their non-forest status on the ground (contrary to the Forest Type Map 2015, which identified the location as a forest) or due to difficult accessibility. The locations of surveyed plots by identified forest class are shown in Figure 8.

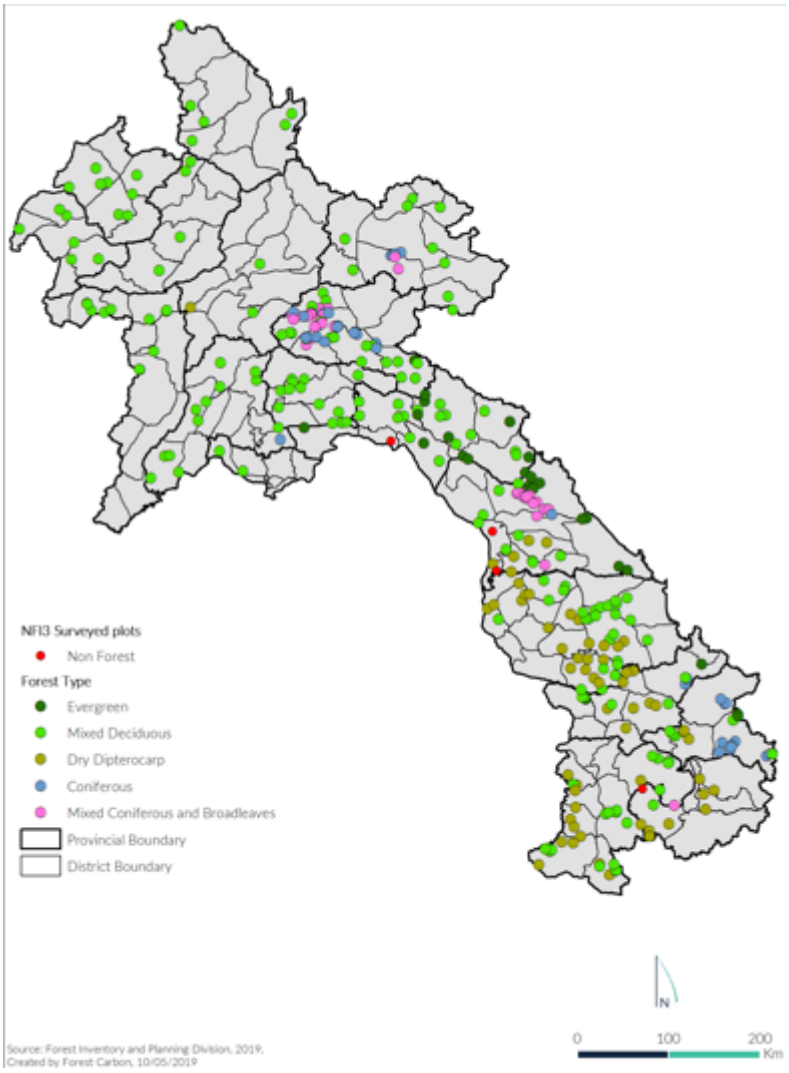


Figure 8: Surveyed plot by forest class in the 3rd NFI

The Below Ground Biomass (BGB) was estimated by using the best available Root-to-Shoot (R/S) ratios corresponding to each forest class and their average AGB.

Table 8 : Root-to-Shoot ratios by forest class and AGB threshold

Forest class	AGB threshold	Root-to-Shoot ratio (R/S ratios)	Source
EG, DD, MD, and MCB	AGB < 125t/ha	0.20	IPCC GL 2006 for National Greenhouse Gas Inventories (Chapter 4: Forest land, Table 4.4)
	AGB > 125t/ha	0.24	
CF	AGB < 50t/ha	0.46	2003 IPCC Good Practice Guidance for LULUCF (Chapter 3: LULUCF Sector Good Practice Guidance, Table 3 A.1.8)
	AGB = 50 - 150t/ha	0.32	
	AGB > 150t/ha	R/S = 0.23	

The estimated biomass was converted into carbon stock with the generic formula below:

$$Ci = TBi \times CF$$

Where:
TBi = total biomass of plot i (include AGB and BGB), expressed in kg.
CF = IPCC default carbon fraction value 0.46 or 0.47 depending on the land/forest class (2006 IPCC GL Volume 4, Chapter 4)

The resulting average carbon stock by forest class and analytical considerations are shown in Table 9. The data in this table includes the three carbon pools which were measured, namely AGB, BGB and DW. However, the analysis hereafter includes only the two carbon pools, namely AGB and BGB, which were used in the National FREL/FRL for the sake of consistency.

The DD forests represent the lowest carbon stock value of 50.80 tC/ha among all forest classes, showing the same trend with the 2nd NFI. The MD and MCB forests showed similar carbon stocks of 87.91 tC/ha and 87.59 tC/ha. The CF forests, by comparison held 77.10 tC/ha, while the larger and generally more remote EG forests held 205.78 tC/ha.

As mentioned in the above chapters, some parts of AGB such as Sapling, Non-Timber Vegetation (NTV), and Bamboo were not measured in this survey.

Table 9: Nation-wide total carbon stocks by forest class

Forest class	Number of plots	Carbon stock (tC/ha)	StD (tC/ha)	StE (tC/ha)	CI (90%)	Uncert ainty (90%)	CI (95%)	Uncert ainty (95%)	Minimum (tC/ha)	Maximum (tC/ha)
Including AGB, BGB and DW										
EG	34	215.69	61.00	10.46	17.21	8.21	20.50	9.51	116.22	346.45
MD	185	93.96	32.27	2.37	3.90	4.17	4.65	4.95	31.38	211.84
DD	62	53.35	16.87	2.14	3.52	6.71	4.20	7.87	24.78	108.23
CF	40	81.41	30.39	4.81	7.90	9.95	9.42	11.57	33.86	146.42
MCB	38	92.21	39.78	6.45	10.62	11.81	12.65	13.72	31.95	182.83
Including AGB and BGB										
EG	34	205.78	62.61	10.74	17.66	8.83	21.05	10.23	112.22	340.25
MD	185	87.91	29.51	2.17	3.57	4.08	4.25	4.84	28.58	187.44
DD	62	50.80	16.73	2.12	3.49	6.99	4.16	8.20	23.71	107.16
CF	40	77.10	27.58	4.36	7.17	9.53	8.55	11.08	32.33	134.12
MCB	38	87.59	38.76	6.29	10.34	12.11	12.32	14.07	30.10	179.01

For each forest class, the minimum target number of plots (i.e. cluster plot level) of 30 for all forest classes was achieved. This was an improvement from the 2nd NFI where CF and EG did not reach this minimum threshold. Although some of the forest classes did not achieve the targeted number of plots calculated from the Winrock Sample Plot Calculator spreadsheet (see Table 2), this has little effect on the results as all forest classes achieved their assigned uncertainty target. As Table 9 shows, the uncertainty targets at a 90% CI were lower than 10% for EG, MD, DD, and lower than 20% for CF and MCB.

Carbon Pools

Based on the learnings of the 2nd NFI, this 3rd NFI focused only on the significant carbon pools that represent individually at least 10% of the total carbon stock. Though Dead Wood represented at the most 10% (for CF in 2nd NFI), it was kept in the measurements to enable the assessment of the impact of selective logging (through measurement of stumps). Table 10 below breaks down each carbon pool including all forest classes: AGB (Living tree, Sapling, Bamboo and NTV), BGB, DW (Standing Dead Wood, Stumps and Lying Dead Wood). The AGB pool represented about 74 – 79% of the total carbon stock for each forest class. The BGB pool ranged between 17% and 20% of the total carbon stock for each forest class, thus also considered as an important carbon pool. Dead Wood represents a relatively small part of the whole carbon stock, and at most 6.44% for MD.

Table 10. Nation-wide carbon stock by carbon pool and forest class

Carbon pool	Forest Type	N	Carbon stock (tC/ha)	StD (tC/ha)	% of Strata
AGB	**EG**	**34**	**166.19**	**50.43**	**77.05%**
	MD	**185**	**72.26**	**23.53**	**76.90%**
	DD	**62**	**42.19**	**13.47**	**79.08%**
	CF	**40**	**60.58**	**22.91**	**74.41%**
	MCB	**38**	**71.42**	**30.94**	**77.45%**
Living tree	EG	34	165.24	50.43	76.61%
	MD	185	67.97	23.53	72.34%
	DD	62	40.57	13.47	76.04%
	CF	40	59.10	22.91	72.60%
	MCB	38	70.15	30.94	76.08%
Sapling	EG	23	0.42	0.16	0.19%
	MD	227	0.65	0.37	0.69%
	DD	101	0.32	0.24	0.60%
	CF	24	0.30	0.26	0.37%
	MCB	45	0.48	0.39	0.52%
Bamboo	EG	23	0.03	0.10	0.01%
	MD	227	3.02	7.92	3.21%
	DD	101	0.24	1.14	0.45%
	CF	24	0.11	0.51	0.14%
	MCB	45	0.07	0.25	0.08%
NTV	EG	23	0.50	0.20	0.23%
	MD	227	0.62	0.44	0.66%
	DD	101	1.06	0.44	1.99%
	CF	24	1.07	0.72	1.31%
	MCB	45	0.72	0.45	0.78%
BGB	**EG**	**34**	**39.60**	**12.18**	**18.36%**
	MD	**185**	**15.65**	**5.98**	**16.66%**
	DD	**62**	**8.61**	**3.27**	**16.14%**
	CF	**40**	**16.51**	**4.76**	**20.28%**
	MCB	**38**	**16.17**	**7.83**	**17.54%**
Dead Wood	**EG**	**34**	**9.90**	**10.97**	**4.59%**
	MD	**185**	**6.05**	**8.78**	**6.44%**

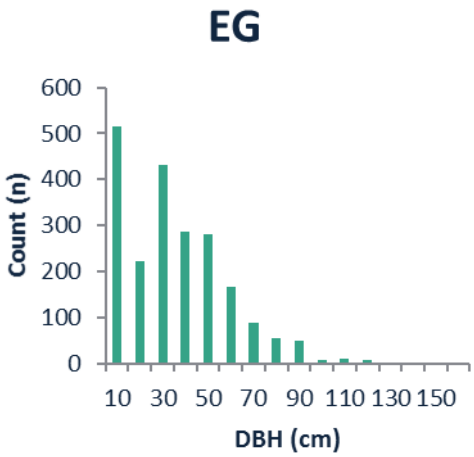
	DD	**62**	**2.55**	**3.81**	**4.79%**
	CF	**40**	**4.31**	**9.93**	**5.30%**
	MCB	**38**	**4.62**	**3.98**	**5.01%**
Standing Dead Wood	EG	34	7.43	11.17	3.44%
	MD	185	3.52	8.78	3.74%
	DD	62	1.37	3.79	2.57%
	CF	40	3.05	10.08	3.75%
	MCB	38	2.67	4.05	2.90%
Stump	EG	34	0.09	0.20	0.04%
	MDF	185	0.07	0.14	0.07%
	DD	62	0.11	0.13	0.21%
	CF	40	0.12	0.17	0.15%
	MCB	38	0.10	0.13	0.11%
Lying Dead Wood	EG	23	2.38	2.73	1.10%
	MD	227	2.47	4.31	2.63%
	DD	101	1.07	1.49	2.01%
	CF	24	1.14	1.26	1.40%
	MCB	45	1.85	1.70	2.01%
AGB+BGB	**EG**	**34**	**205.78**	**62.61**	**95.41%**
	MD	**185**	**87.91**	**29.51**	**93.56%**
	DD	**62**	**50.80**	**16.73**	**95.21%**
	CF	**40**	**77.10**	**27.58**	**94.70%**
	MCB	**38**	**87.59**	**38.76**	**94.99%**
Total (AGB, BGB and Deadwood)	**EG**	**34**	**215.69**	**60.10**	**100.00%**
	MD	**185**	**93.96**	**32.18**	**100.00%**
	DD	**62**	**53.35**	**16.73**	**100.00%**
	CF	**40**	**81.41**	**30.01**	**100.00%**
	MCB	**38**	**92.21**	**39.26**	**100.00%**

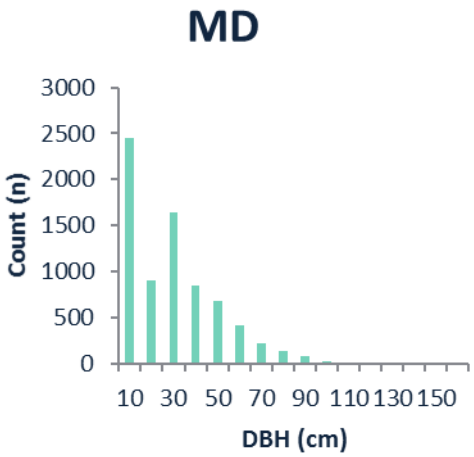
*1 Sapling, Bamboo, NTV and Lying Dead Wood data are cited from the result of 2nd NFI.

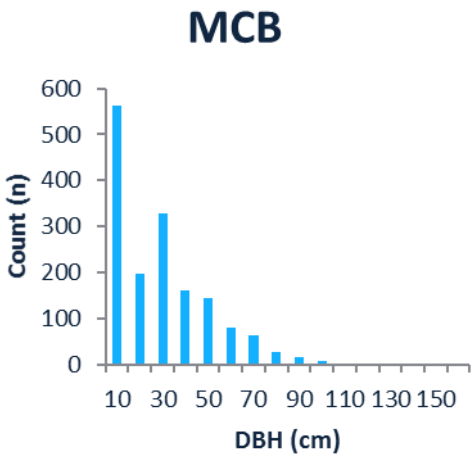
*2 Due to rounding, numbers presented in the table above may not add up precisely to the summed figures and percentages may not precisely reflect the absolute figures.

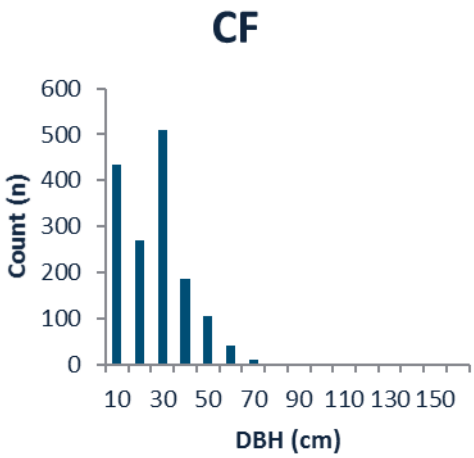
DBH Distribution

Stand tables for each of the five forest class across all provinces are summarized below. The tables show a largely uniform pattern across each of the forest classes. The distribution is as expected for secondary and disturbed forests, with a large population of smaller individuals in the 10-50cm DBH range, tapering off as individual trees of larger DBH become scarcer and harder to locate.









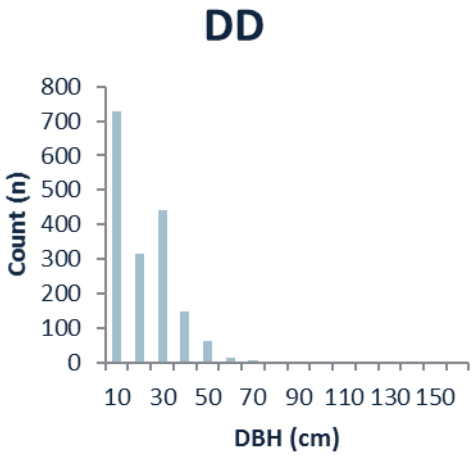


Figure 9: DBH (cm) distribution by forest class

Such DBH distributions can be explained in a number of ways depending on forest class, locality and influence/role of human populations on the landscape. Distribution curves shifted to the left are often indicative of selective logging, fire clearance and subsequent secondary regrowth which can be hampered from full-scale recovery by the presence of more aggressive bamboo species.

Non Timber Forest Products (NTFPs)

NTFPs were found in 82% of all sampled plots. Some form of NTFP was found in all EG plots, while a majority of MCB and MD plots also featured some form of NTFP (92% and 97% respectively). NTFPs were only present in 48% and 40% of CF and DD respectively. Edible plants was the most common NTFP, followed by medicinal plants, fibers, ornamentals, animals or animal products, and extracts.

Table 11: Occurrence of NTFPs in plots as percentage of total number of plots.

Forest class	Edible plants	Medicinal plants	Fibers	Extracts	Ornamentals	Animal or animal products	*Total*
EG	97%	76%	18%	15%	15%	3%	100%
MD	94%	44%	46%	4%	32%	17%	97%
DD	34%	19%	15%	0%	11%	0%	40%
CF	45%	38%	33%	25%	23%	15%	48%
MCB	87%	34%	0%	0%	13%	5%	92%
Total	77%	41%	31%	6%	24%	11%	82%

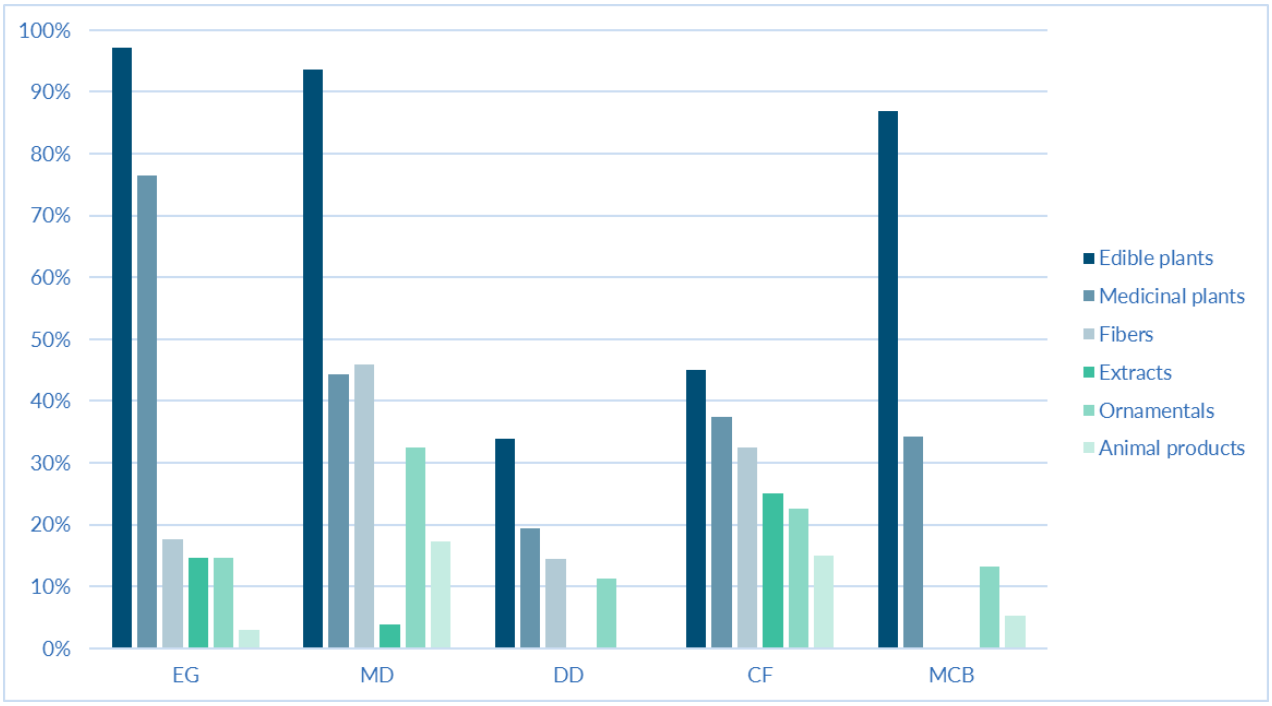


Figure 10. Percentage occurrence by type of NTFP per forest class

While EG contained at least one NTFP in all of its surveyed plots, they were mainly edible plants and medicinal plants. In MD plots, all NTFP types were found but medicinal plants were found at a lower rate than in EG. In contrast, fibers, ornamentals and animal products were found at higher rate in MD than in EG. CF where all six types of NTFPs were found, also proved as a significant source for NTFPs. In MCB plots, medicinal plants and especially edible plants can be found, while in DD plots extracts as well as animal products were not found.

5.2 Quality Control (QC) survey

For quality control (QC) purposes, random re-sampling of plots was planned by the QC team for a total of 50 plots. The QC team managed to reach 49 plots of which 47 plots were found to be forests representing 13% of the 359 surveyed plots. In comparison with the 2nd NFI, the QC team was more efficient at finding the center of the sub-plots. This was attributable to the change in the QC team composition where the QC team went to the plot sites with the villagers and the DAFO and PAFO staff who actually joined the original survey.

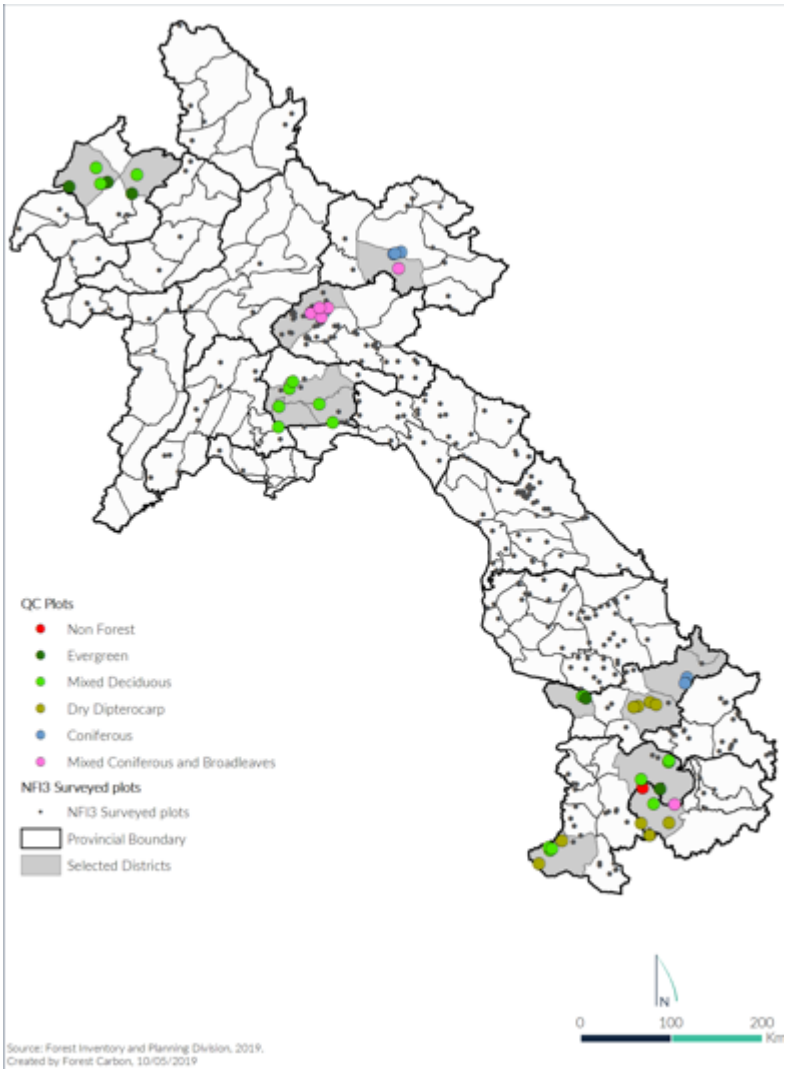


Figure 11: Location of NFI QC plots

Identification of the forest class in the field was challenging for most of the teams including for the QC team. Consequently, there were discrepancies in the forest classes identified by the survey teams and the QC team. For the purpose of conducting statistical comparison of the tree measurements by the survey teams (normal sampling) and the QC team (QC sampling), forest classes identified by the survey teams were applied to the QC plots.

Among the 47 usable plots, only one was identified as Evergreen Forest (EG) by the survey team which consequently did not permit statistical comparison for this specific forest class.

A non-parametric multiple comparison test (Wilcoxon Signed-Rank Test for Paired Samples) was carried out to determine the significance of difference between the two measurements; the quality control sampling and the normal sampling on two levels. T-tests were not considered suitable in this case due to the lack of normal distribution of the data. We first tested the means of each quality control plot with the corresponding plot of the

normal sampling (Annex 4), and secondly compared the means of each forest class between the quality control and normal sampling (Table 12). P values of less than 0.05 indicate that there was a statistically significant difference in sampling time 1 (normal sampling) as compared to sampling time 2 (QC sampling) across the entire forest class. P values greater than 0.05 indicate that there is no significant difference between the normal and the resampled QC measurements of each forest class.

As shown in Table 12 below, p-values for all forest classes were greater than 0.05, indicating that there is no significant statistical difference between the carbon stocks as determined by the QC compared to that of the normal sampling for the same selection of plots.

Table 12: Comparison of total carbon stocks by forest class between the QC sampling plots and respective normal field sampling plots, including the results of the test for significant differences

	Normal sampling						QC Sampling					
Forest class	**N**	**Carbon stock (tC/ha)**	**StD**	**StE**	**CI (95%)**	**CI (90%)**	**Carbon stock (tC/ha)**	**StD**	**StE**	**CI (95%)**	**CI (90%)**	**p value**
EG	1	228.7					219.0					
MD	21	87.1	35.9	7.8	16.3	13.5	85.3	36.6	8.6	18.2	15.0	0.14
DD	10	53.8	12.4	3.9	8.9	7.2	52.1	8.0	2.7	6.1	5.0	0.64
CF	7	49.0	17.1	7.0	17.9	14.0	49.1	19.4	8.7	24.1	18.5	0.45
MCB	8	54.7	27.9	9.9	23.4	18.7	55.0	28.1	9.4	21.6	17.4	0.83

6. Recommendations

The following recommendations are provided for consideration in the design and implementation of the next iteration of the Lao NFI.

6.1 Revised Design and SOP

The 3rd NFI brought several revisions to the overall design of the NFI and the SOP. This section below outlines the implications of those changes and how they were received by the teams.

Carbon Pools and Plot Design

Reducing the number of carbon pools measured made the survey much faster for the teams, especially removal of the time-consuming bamboo measurements. Small fractions in the total carbon stock such as Sapling, Non-Timber Vegetation (NTV), and Bamboo are not a priority for measurement in every NFI, particularly when resources are constrained.

Plot Checking

The 3rd NFI introduced an additional step in the plot distribution process which is a visual pre-assessment with recent satellite imagery to ensure the plots fall in forested area. This pre-assessment of plots improved the efficiency of the survey as only four surveyed plots were actually not forested as compared to 58 plots during the 2nd NFI. However this step may eliminate plots that do not appear as forests on imagery but that might have been low density forest on the ground. This may be the case more particularly with DD forest that can have a low canopy cover. Technicians must therefore be very cautious and conservative during this pre-assessment step to avoid impact on the resulting carbon stocks.

Number of Sub-Plots

To avoid the issue from the 2nd NFI of having to eliminate plots with no majority forest class, the 3rd NFI distributed between six and ten sub-plots for a cluster plot depending on the landscape fragmentation. The teams were asked to survey a minimum of four sub-plots and eventually more than four sub-plots to achieve a majority for a particular forest class. This change proved to be efficient as no plot was rejected due to conflicting forest classifications, and can be applied also in the next NFI.

The other reason that led to an increase in the number of sub-plots available to be measured, was by replacing the laborious shifting of 100 meters in four directions in the case the sub-plot center did not fall in forest areas. The teams endorsed the change as they previously reported that the former shifting process was time consuming.

Plot Navigation

For this 3rd NFI, the teams were asked to consider first the four sub-plots A, B, C and D but they could navigate to them in any order to optimize the route. Some team leaders proposed that they should be able to go first to any of the ten potential sub-plots which could introduce a bias based on accessibility. The current approach ensures that it is not always the most accessible sub-plots that are surveyed but also allows the teams some flexibility to efficiently navigate the plot. This navigation rule can be applied also in the next NFI.

6.2 Training

In regards to the pre and post-survey trainings (see Section 2.5) recommendations from the 3rd NFI are derived as follows:

Field survey training

Overall, the Team Leaders and field teams felt the training was largely sufficient to feel comfortable with the SOP and knowledgeable on how to use the various equipment provided. However, Team Leaders did express a desire for more field based training than was provided before beginning the actual inventory process. This is so that field teams can learn how to deal with field based realities that are hard to capture in the SOP. Learning how to troubleshoot these scenarios before beginning the actual survey was considered important for the next NFI.

Team Leaders also requested that additional time be spent learning how to both conduct the data inputting in the tablets and how to troubleshoot tablet issues. This can be achieved through both additional classroom training as well as the extended field training where Team leaders will be actively using the tablets to enter field data.

The additional trainings on “Risk assessment and mitigation” as well as the “First aid training” were greatly appreciated by the teams. These training should be re-conducted for the next NFI with an additional component on water rescue as teams do, on occasion, have to traverse rivers and lakes to reach plots.

Remote Sensing & GIS training

The Remote Sensing & GIS training for survey plot distribution was provided to the Forest Information Section under FIPD. The trainees carried out exercises on how to distribute designed plot on ArcGIS software.

Carbon stock calculation training

The last training was the carbon stock calculation training, which was provided to the staff mainly under the Data Processing and Forest Planning Section, FIPD. Some REDD+ division staff also joined the lecture part for their understanding.

These trainings contributed the capacity development of FIPD for sustainable NFI implementation. However, the trainings shall be repeated for the next NFI as FIPD still lack full capacity for designing, implementing and compiling the results independently.

6.3 Field Implementation

Scheduling and Plot Accessibility

Despite a two-month delay which meant the survey only started in January, the teams managed to complete their work before the Lao New Year in April. To achieve this, it seems teams did not take their prescribed rest days and also traveled by night. This is sub-optimal as it leads to increased fatigue and potential risk of harm due to errors in judgement. It should be noted that this was neither required nor requested of the teams; this was a collective decision by the team leaders. Despite their insistence to complete the work quicker than the prescribed amount of time (Table 13), the team leaders claimed that more time should be allocated in the budget to accommodate the travel time between the province capital and the districts, as well as between the districts and the villages.

Furthermore, great care should be applied when preparing and presenting the budget to the teams. Despite clear explanations to the contrary, team leaders perceived the budgeted average of one day per plot as a strict constraint for each plot, i.e. if they determined that a plot might take more than one day to complete they would eliminate the plot based on accessibility issues. Several plots were not surveyed, especially in Xekong province, because the sixth team leader assessed that it would take more days to complete the plot than was assigned in the budget. While a whole day meeting was conducted for this 3rd NFI with the teams to review plot locations and identify locations that might be inaccessible or require additional budget for boats or other vehicles, for the next NFI this meeting could also be used as an opportunity to identify a specific number of days per plot to estimate the team's budget, rather than take a single one-day per plot average.

For the reasons mentioned above, the teams tended to survey only the most accessible plots which may have had implication on the biomass measurements. The next iteration of the NFI may include an analysis on potential correlation between biomass and the accessibility to inform if the plot distribution should consider strata based on the accessibility. Even if accessibility is carefully assessed, the exact necessary amount of time cannot be estimated. If budget divisions are imbalanced and cause elimination of the plots by survey teams, FIPD has to manage this issue to maximize the plots to be surveyed regardless of distance to avoid accessibility bias.

The necessary budget for each team were calculated based on the "one day per plot" rule, in which teams would need one day to complete one plot, and allocated to each team (Table 13). However, all the teams came back to Vientiane earlier than expected as mentioned above, which are shown in the actual survey days in Table 13. The necessary days for pure field work were obtained by excluding the prescribed days counted towards travel and courtesy calls to PAFO and DAFOs from the actual survey days and shown as "pure survey days" in Table 13. It should be noted that the pure survey days includes all the days spent in the field which includes the cases that teams found non-forest and did not survey.

To assess budget efficiency, the pure survey days were divided by target plots (Table 13). Team 1 and Team 3 took more than one day but the other teams took less than one day to complete one plot. Even though the average of actual survey days per plots is less than one but careful assessment on budget allocation is necessary in NFI planning.

Table 13: Survey days

Team	Planned survey days	Actual survey days	Pure survey days	target plots	actual days per plot
1	110	74	54	45	1.20
2	102	78	68	76	0.89
3	101	83	73	61	1.20
4	105	69	46	74	0.62
5	128	64	56	90	0.62
6	92	58	49	69	0.71
Total/Average	638	426	346	415	0.83

Field Safety

The 3rd NFI provided specific trainings on risk mitigation and first aid. However teams are still not fully considering safety issues as explained above. For the next NFI, besides re-conducting the "safety" trainings, it may be worth considering to set up a monitoring team that would be stationed at FIPD with the duty to follow daily the work of each team to ensure that they respect their timeline and their rest days.

Forest Class Identification

Similar to the 2nd NFI, there was low correspondence between the forest class identified on the ground by the survey team and the predicted forest class from Forest Type Map 2015 generated by the FIDP remote-sensing section. This resulted in a low correlation rate for EG, where only 34 plots were identified as such by the teams among the 144 map identified EG plots. To solve this issue the field reviewing including remote-sensing section and inventory teams shall be organized before the iteration of the next NFI to make the common understanding for identification of forest classes.

Navigation to Plots

The field teams greatly appreciated the availability of both the GPS units and tablets loaded with the maps to support navigation to the plots. Besides the often-difficult terrain to reach the plots, the teams found these two pieces of technology helpful in finding their ways to the survey plots.

Additional topographic map were uploaded onto the tablets for navigation purposes, but this was not used by the teams as the names (rivers and mountains) were in English. For the next NFI, research for more relevant dataset must be undertaken and anticipated from other organizations (National Geographic Department) or open-source datasets (Open Street map).

The 3rd NFI still used the 2015 RapidEye (5 meters resolution) as the main satellite imagery uploaded onto the tablets. Water-proof maps with 2019 Sentinel-2 imagery were also printed-out for all the teams. While the 10 meters resolution of the Sentinel-2 is sufficient for the maps, it is not accurate enough to replace a finer imagery like the RapidEye for navigation purposes. If up-to-date imagery with at least 5-meter resolution are available, that will help the plot navigation in future NFIs.

The use of the same district staff and villagers that accompanied the first inventory team, greatly facilitated the ability of the QC team to find the plots for re-measurement.

Tablet Use and Data Collection

All teams were greatly appreciative of the tablets, their multi-functionality and the extent to which they facilitate the data collection process. Although no tablets were damaged during the implementation of the NFI, greater attention should be placed on protecting these tablets and ensuring their continued functionality throughout the survey season, considering the central role they play in the NFI survey. As such, for future NFIs it is recommended to purchase heavy duty, waterproof tablet cases. Additionally, while spare battery packs were provided for the current field season, the teams recommend that higher storage battery packs be provided next time for times when the teams must spend upwards of two days in the forest to inventory a plot. The future NFIs should take into account enough lead-time to prepare such equipment as it may require importing from other countries.

6.4 Quality Control

To ensure that the QC team conducted enough plots and meet minimum sampling sizes per forest class, additional number of plots should be assigned to the QC team. For this round, though the QC team should re-measure a minimum of 10% of the plots, they were assigned 50 plots which is 14% of the total 359 plots, so that in case a plot becomes inaccessible or is already converted to another land-use at the time of the QC team's arrival, the prescribed minimum can still be achieved. As a result, the QC team was able to survey 47 plots which is 13% of the total 359 plots. The future NFIs are recommended to follow the same methods to ensure enough number of QC plots will be surveyed.

When re-measuring the plots, the QC team is never sure in which direction the slope measurement took place, which can have a great impact on the nest sizes and therefore the whole sub-plot measurements. One idea for the future NFIs could be to install an additional metal pole, painted in blue (the center metal pole being painted in red), is installed close to the center to indicate the slope direction.

6.5 Survey Monitoring

As mentioned in the field safety passage, for the need of the survey monitoring, a team (approximately two FIPD staff) based in Vientiane may have the following duties to ensure the smooth and consistent implementation of the survey:

- Regular communication with the team to ensure that progress and rest days follow the work plan,
- Advise the team in the case plots are unreachable and provide additional plot locations as necessary,
- Check the data entry and consistency of the collected measurements.

7. References

DOF Lao PDR and JICA (2014): Validation and Registration of the Project on REDD plus through Participatory Land and Forest Management for Avoiding Deforestation in Lao PDR (Technical Cooperation Report)

DOF Lao PDR and JICA (2014): Lao PDR NFI Standard Operating Procedure (SOP) Manual for Terrestrial Carbon Measurement

DOF Lao PDR and JICA (2017): The 2nd National Forest Inventory Survey in Lao People's Democratic Republic

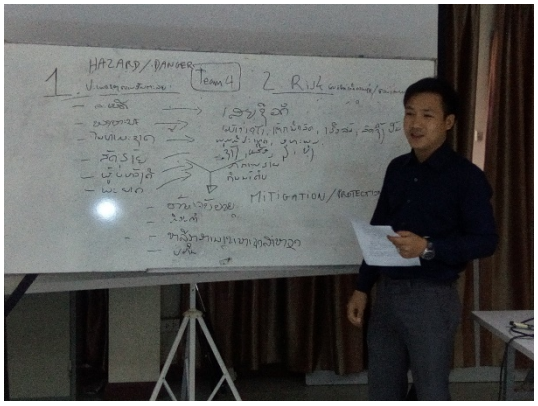
DOF Lao PDR and JICA (2018): Lao PDR NFI Standard Operating Procedure (SOP) Manual for Terrestrial Carbon Measurement

8. Annexes

Annex 1: Activity photos

Kick-of meeting in October 2018

Practicing how to use tablets
at a classroom training



Risk assessment and mitigation training

First aid training provided
by Vientiane Rescue

Measuring tree DBH in field training

Measuring distance using DME device

Group photo after a field training

Refresher training before the survey launching in January

Preparing survey tools and equipment

Recently deforested plot visited by a QC team

RS & GIS training on plot distribution

Carbon stock calculation training

Annex 2: Equipment list

Item	Quantity	Remark
Tablet with case & screen protector	2	
Power bank for tablet	1	
Cable and adapter for tablet	1	
Charger for tablet in the car	1	
Internet sim card for tablet	1	
Telephone card for prepaid internet	many	
GPS	2	
AA battery for GPS	many	
DME unit (silver box)	1	
DME Responder	1	
DME Handy	2	
9V battery for DME	many	
Measuring tape (50m)	2	
DBH tape	2	
Clinometer	1	
Plastic tarp	1	
Spray	many	
Pens	many	
Pencils	many	
Pencil sharpeners	many	
Erasers	many	
Small notebooks	many	
Machete	2	
Sharpener	2	
Hoe	1	
Round shovel	2	
Handel for hoe & round shovel	3	
Small round shovel	1	
Backpack	2	
First Aid kit with Medicine	1	
Iron poles	63	in total
Metal detector	1	QC team only
battery for metal detector	many	

Annex 3: Surveyed Plot Information

Plot ID	Province	Forest class	Coordination		AGB		BGB	
			X	Y	tB/ha	tC/ha	tB/ha	tC/ha
1	Houaphan	MD	104.3980277	19.79892919	165.16	77.63	39.64	18.63
2	Xiengkhouang	MCB	103.1288973	19.67667808	66.63	31.32	13.33	6.26
3	Xiengkhouang	MCB	103.2079947	19.67832504	99.71	46.86	19.94	9.37
4	Houaphan	MD	104.4443539	19.66357335	209.75	98.58	50.34	23.66
5	Xiengkhouang	CF	102.8693957	19.64582614	166.60	78.30	38.32	18.01
6	Xiengkhouang	MCB	102.884006	19.62599988	152.56	71.70	36.61	17.21
7	Xiengkhouang	MCB	103.044208	19.63201423	79.42	37.33	15.88	7.47
8	Xiengkhouang	CF	103.0509049	19.63213577	84.27	39.60	26.97	12.67
9	Xiengkhouang	CF	103.1644403	19.62914465	85.20	40.04	27.26	12.81
10	Xiengkhouang	CF	103.2186097	19.63627576	94.35	44.34	30.19	14.19
12	Xiengkhouang	MCB	102.8558715	19.61803812	134.53	63.23	32.29	15.18
13	Xiengkhouang	MD	102.8912727	19.6059212	134.30	63.12	32.23	15.15
14	Xiengkhouang	CF	102.9689479	19.59847581	129.53	60.88	41.45	19.48
15	Xiengkhouang	MCB	103.0068349	19.59806451	75.55	35.51	15.11	7.10
16	Xiengkhouang	MCB	103.0422534	19.6225027	93.06	43.74	18.61	8.75
17	Xiengkhouang	MCB	103.1642305	19.61628903	146.82	69.01	35.24	16.56
18	Xiengkhouang	MCB	102.8721164	19.57215726	111.00	52.17	22.20	10.43
19	Xiengkhouang	MCB	102.8876867	19.58710735	124.84	58.67	24.97	11.73
20	Xiengkhouang	MCB	103.1487161	19.58764844	101.42	47.67	20.28	9.53
21	Xiengkhouang	CF	103.1171067	19.50605765	54.71	25.71	17.51	8.23
22	Xiengkhouang	MD	102.8365394	19.43713733	203.42	95.61	48.82	22.95
23	Xiengkhouang	MD	102.8577498	19.43521305	122.52	57.58	24.50	11.52
24	Xiengkhouang	CF	103.4822415	19.44731581	87.24	41.00	27.92	13.12
25	Xiengkhouang	CF	103.4984153	19.42148304	93.93	44.14	30.06	14.13
26	Xiengkhouang	MD	103.2747942	19.39508876	192.74	90.59	46.26	21.74
27	Xiengkhouang	CF	103.1803092	19.34972678	208.43	97.96	47.94	22.53
28	Xiengkhouang	CF	103.6843768	19.33481315	156.42	73.52	35.98	16.91
29	Xiengkhouang	CF	103.0114339	19.39318405	121.50	57.10	38.88	18.27
30	Xiengkhouang	CF	103.691745	19.28725939	118.91	55.89	38.05	17.88
31	Vientiane	CF	102.7458769	18.38751673	123.98	58.27	39.67	18.65
32	Khammouan	MCB	105.1737809	17.82913354	137.27	64.52	32.94	15.48
33	Khammouan	MCB	105.2741722	17.77448567	256.93	120.76	61.66	28.98

35	Khammouan	MCB	105.2720267	17.63400606	202.48	95.17	48.60	22.84
36	Khammouan	CF	105.4213615	17.65139796	138.76	65.22	44.40	20.87
37	Salavan	CF	106.7490506	16.03379915	80.00	37.60	25.60	12.03
38	Salavan	CF	106.7336902	15.98089195	57.94	27.23	18.54	8.71
39	Xekong	CF	107.087099	15.83458546	149.98	70.49	47.99	22.56
40	Xekong	CF	107.1364005	15.79432051	193.03	90.72	44.40	20.87
42	Xekong	CF	107.1244414	15.78949316	199.69	93.85	45.93	21.59
43	Xekong	MD	107.293971	15.47281732	166.98	78.48	40.07	18.83
46	Xekong	EG	107.4971019	15.40796528	263.29	123.75	63.19	29.70
48	Xekong	CF	107.0694207	15.31445065	130.47	61.32	41.75	19.62
49	Xekong	CF	107.175618	15.33574437	172.26	80.96	39.62	18.62
52	Xekong	CF	107.5721108	15.29358993	134.31	63.13	42.98	20.20
55	Xekong	CF	107.5342712	15.2741971	185.41	87.14	42.64	20.04
56	Champasak	MD	105.35402	14.35882136	186.91	87.85	44.86	21.08
57	Champasak	MD	105.4003514	14.33491345	114.40	53.77	22.88	10.75
58	Phongsaly	MD	101.7501978	22.46478697	151.80	71.35	36.43	17.12
59	Houaphan	CF	103.9333019	20.22909692	50.17	23.58	16.05	7.55
60	Houaphan	CF	103.8590586	20.21078988	54.36	25.55	17.40	8.18
61	Houaphan	CF	103.8756055	20.21501089	136.00	63.92	43.52	20.45
62	Houaphan	MCB	103.8756181	20.18510379	129.83	61.02	31.16	14.64
65	Houaphan	MD	104.8361478	20.06362315	79.62	37.42	15.92	7.48
66	Louangphabang	DD	101.8579627	19.69069229	140.95	66.25	33.83	15.90
67	Khammouan	MD	104.7003527	17.56495732	70.08	32.94	14.02	6.59
69	Khammouan	DD	105.1931783	17.39344611	64.02	30.09	12.80	6.02
70	Khammouan	DD	105.3698364	17.37439358	92.22	43.35	18.44	8.67
71	Khammouan	MD	104.9679135	17.30761379	82.50	38.78	16.50	7.76
72	Khammouan	DD	105.0461727	17.23630868	106.05	49.84	21.21	9.97
73	Khammouan	MD	105.5100795	17.24212246	130.95	61.55	31.43	14.77
74	Khammouan	MD	105.228639	17.19596566	133.67	62.83	32.08	15.08
75	Khammouan	MD	105.2321073	17.1771164	157.56	74.05	37.81	17.77
76	Khammouan	DD	104.8419513	17.16246282	72.78	34.21	14.56	6.84
78	Savannakhet	DD	105.0238665	17.0877713	50.39	23.68	10.08	4.74
79	Savannakhet	DD	105.2065113	17.01263781	85.74	40.30	17.15	8.06
80	Savannakhet	DD	105.0944975	16.97086743	111.41	52.36	22.28	10.47

81	Savannakhet	DD	105.0876242	16.85068682	55.64	26.15	11.13	5.23
82	Savannakhet	DD	105.1605767	16.86320461	100.58	47.27	20.12	9.45
83	Savannakhet	DD	105.1973241	16.86355581	47.52	22.33	9.50	4.47
84	Savannakhet	DD	105.1247178	16.80507603	74.00	34.78	14.80	6.96
85	Savannakhet	MD	105.3927019	16.80444789	58.91	27.69	11.78	5.54
86	Savannakhet	DD	104.8488069	16.76258573	73.49	34.54	14.70	6.91
88	Savannakhet	DD	104.7878151	16.72181322	57.93	27.22	11.59	5.44
89	Savannakhet	DD	105.6074309	16.66630528	77.21	36.29	15.44	7.26
90	Savannakhet	MD	105.7850885	16.62459773	109.60	51.51	21.92	10.30
91	Savannakhet	MD	104.896126	16.62167605	93.06	43.74	18.61	8.75
92	Savannakhet	DD	105.6863132	16.61593562	77.76	36.55	15.55	7.31
93	Savannakhet	DD	105.384243	16.53542681	107.41	50.48	21.48	10.10
94	Savannakhet	DD	105.7890679	16.38400588	89.63	42.13	17.93	8.43
95	Savannakhet	DD	105.9347034	16.36037675	53.71	25.25	10.74	5.05
96	Savannakhet	DD	106.0715846	16.3532386	98.66	46.37	19.73	9.27
97	Savannakhet	DD	105.5218462	16.32886922	76.46	35.94	15.29	7.19
98	Savannakhet	DD	105.6820202	16.2359303	92.82	43.63	18.56	8.73
99	Savannakhet	DD	105.7747284	16.22903665	72.98	34.30	14.60	6.86
100	Savannakhet	DD	105.9300107	16.21992233	123.59	58.09	24.72	11.62
102	Savannakhet	DD	105.607736	16.13724927	127.06	59.72	30.49	14.33
103	Savannakhet	DD	105.7534822	16.12288709	121.73	57.21	24.35	11.44
104	Salavan	DD	106.226731	16.11231324	74.37	34.95	14.87	6.99
105	Salavan	DD	106.154803	16.09559683	69.46	32.65	13.89	6.53
106	Savannakhet	DD	105.8374717	16.04044835	110.75	52.05	22.15	10.41
107	Savannakhet	DD	106.1228819	16.00151173	83.00	39.01	16.60	7.80
108	Savannakhet	DD	105.8860534	15.99372762	99.15	46.60	19.83	9.32
110	Salavan	DD	106.3757024	15.80542938	65.07	30.58	13.01	6.12
111	Salavan	DD	106.3877639	15.79695893	107.25	50.41	21.45	10.08
112	Salavan	DD	106.2724146	15.75437232	106.74	50.17	21.35	10.03
113	Salavan	DD	106.4460693	15.77077026	105.64	49.65	21.13	9.93
114	Salavan	DD	106.2271309	15.74381825	80.64	37.90	16.13	7.58
115	Salavan	DD	106.1512856	15.55010622	177.24	83.30	42.54	19.99
116	Xekong	DD	106.7248565	15.52424876	54.61	25.67	10.92	5.13
117	Xekong	DD	106.7231403	15.51142629	53.33	25.06	10.67	5.01

118	Xekong	DD	106.7693965	15.44171371	185.90	87.37	44.62	20.97
121	Champasak	DD	105.5824078	15.08924806	82.97	39.00	16.59	7.80
123	Attapeu	DD	106.8771896	15.04795855	89.27	41.96	17.85	8.39
124	Champasak	DD	106.2995533	15.03268098	87.51	41.13	17.50	8.23
125	Champasak	DD	105.6670484	14.98998022	62.93	29.58	12.59	5.92
126	Attapeu	DD	107.0229611	14.93552576	63.08	29.65	12.62	5.93
127	Champasak	DD	105.6526861	14.93615101	125.56	59.01	30.13	14.16
128	Attapeu	DD	106.9193389	14.90202153	72.88	34.25	14.58	6.85
129	Champasak	MCB	106.6279622	14.7884431	61.35	28.83	12.27	5.77
130	Champasak	DD	105.6549911	14.76922302	91.57	43.04	18.31	8.61
131	Attapeu	DD	106.9388149	14.74887775	140.49	66.03	33.72	15.85
132	Champasak	DD	105.6089863	14.64821189	93.04	43.73	18.61	8.75
133	Attapeu	DD	106.2967819	14.6010918	76.65	36.03	15.33	7.21
134	Attapeu	DD	106.5756614	14.60862014	95.86	45.05	19.17	9.01
135	Champasak	DD	105.6399798	14.57592489	105.21	49.45	21.04	9.89
136	Attapeu	DD	106.3848267	14.53713231	42.69	20.07	8.54	4.01
137	Champasak	DD	105.7049606	14.48303768	70.84	33.29	14.17	6.66
138	Attapeu	DD	106.382299	14.48500659	65.39	30.74	13.08	6.15
139	Champasak	DD	105.5203189	14.43161622	113.26	53.23	22.65	10.65
140	Champasak	DD	105.6306952	14.41921326	69.20	32.53	13.84	6.51
141	Champasak	DD	105.8908904	14.21483053	80.83	37.99	16.17	7.60
142	Champasak	DD	105.2905361	14.20430789	98.34	46.22	19.67	9.24
143	Champasak	MD	105.8928667	14.18981927	84.83	39.87	16.97	7.97
145	Champasak	DD	105.991826	14.10317763	121.38	57.05	24.28	11.41
146	Xaignabouly	MD	100.8430949	19.72315073	156.44	73.52	37.54	17.65
147	Xaignabouly	MD	100.8369462	19.73003693	218.01	102.47	52.32	24.59
148	Xaignabouly	MD	100.8807747	19.66093638	129.37	60.81	31.05	14.59
149	Xaignabouly	MD	101.6218528	19.66112158	131.48	61.79	31.55	14.83
150	Xaignabouly	MD	101.0116884	19.64077252	117.84	55.38	23.57	11.08
151	Xaignabouly	MD	101.6215328	19.65074545	157.88	74.20	37.89	17.81
154	Xiengkhouang	CF	103.0015816	19.38973599	165.24	77.66	38.01	17.86
155	Xiengkhouang	MD	103.6575273	19.31157961	106.21	49.92	21.24	9.98
156	Xaignabouly	MD	101.3329489	19.25688631	122.06	57.37	24.41	11.47
157	Xaignabouly	MD	101.353144	19.07938189	111.22	52.27	22.24	10.45

158	Xiengkhouang	EG	104.0678634	19.16987234	584.24	274.59	140.22	65.90
159	Xiengkhouang	MD	104.0928711	19.13828636	223.83	105.20	53.72	25.25
161	Xaignabouly	MD	101.3572451	19.07610685	120.87	56.81	24.17	11.36
162	Vientiane	MD	102.4963378	19.05742987	179.49	84.36	43.08	20.25
165	Vientiane	MD	102.5091075	18.97401115	134.61	63.26	32.31	15.18
166	Xaisomboun	MD	102.8551813	18.98377884	59.32	27.88	11.86	5.58
167	Xaisomboun	MD	102.9804552	18.98132617	106.99	50.29	21.40	10.06
168	Xiengkhouang	MD	103.9372164	19.00262555	159.01	74.74	38.16	17.94
169	Xiengkhouang	MD	104.0740674	18.99006522	142.35	66.90	34.16	16.06
171	Vientiane	MD	102.1494472	18.90882484	100.22	47.10	20.04	9.42
173	Xaisomboun	MD	102.9460263	18.89656296	156.89	73.74	37.65	17.70
175	Xaisomboun	MD	102.7478349	18.86879438	102.37	48.11	20.47	9.62
178	Bolikhamxai	MD	103.5542501	18.84110317	224.72	105.62	53.93	25.35
179	Vientiane	MD	102.0108998	18.76281653	120.36	56.57	24.07	11.31
181	Bolikhamxai	EG	104.1656288	18.76711498	377.47	177.41	90.59	42.58
183	Xaisomboun	MD	103.1271879	18.73373045	239.19	112.42	57.41	26.98
184	Bolikhamxai	MD	103.5196401	18.75994439	117.27	55.12	23.45	11.02
185	Bolikhamxai	EG	104.1654073	18.76259131	266.23	125.13	63.89	30.03
187	Bolikhamxai	MD	103.9085167	18.73533097	204.89	96.30	49.17	23.11
188	Bolikhamxai	MD	104.3185635	18.73721296	252.04	118.46	60.49	28.43
189	Vientiane	MD	101.9123501	18.68432554	263.66	123.92	63.28	29.74
190	Xaisomboun	MD	103.3183929	18.65751661	132.84	62.44	31.88	14.98
193	Bolikhamxai	MD	104.1011304	18.6747599	172.56	81.10	41.41	19.46
194	Bolikhamxai	MD	104.7591452	18.66813384	212.10	99.69	50.90	23.92
197	Bolikhamxai	MD	103.907297	18.60754789	215.24	101.16	51.66	24.28
198	Bolikhamxai	MD	103.9607863	18.61605523	145.70	68.48	34.97	16.43
199	Bolikhamxai	MD	104.3205443	18.61859248	166.96	78.47	40.07	18.83
200	Bolikhamxai	EG	105.0930028	18.61471983	242.36	113.91	58.17	27.34
201	Xaignabouly	MD	101.7151188	18.55047469	79.65	37.44	15.93	7.49
202	Xaisomboun	MD	103.3499164	18.5540602	180.17	84.68	43.24	20.32
204	Bolikhamxai	EG	102.9795445	18.50340534	333.25	156.63	79.98	37.59
206	Bolikhamxai	EG	103.2864584	18.47041983	540.43	254.00	129.70	60.96
208	Bolikhamxai	EG	104.1580067	18.35443294	473.28	222.44	113.59	53.39
212	Bolikhamxai	MD	105.0729742	18.23585202	207.98	97.75	49.92	23.46

213	Bolikhamxai	EG	105.1947137	18.21699701	582.89	273.96	139.89	65.75
218	Khammouan	MD	105.0893174	17.95714226	217.81	102.37	52.27	24.57
219	Khammouan	EG	105.3022097	17.96105673	339.78	159.70	81.55	38.33
222	Khammouan	MD	104.8999872	17.88731451	180.15	84.67	43.24	20.32
223	Khammouan	EG	105.2034807	17.88568402	363.97	171.07	87.35	41.06
230	Khammouan	MD	104.7436122	17.64641023	180.34	84.76	43.28	20.34
231	Khammouan	MD	105.7413403	17.61050195	113.06	53.14	22.61	10.63
233	Khammouan	MD	105.3508232	17.15502975	130.43	61.30	31.30	14.71
235	Savannakhet	MD	105.5520628	16.94426239	159.21	74.83	38.21	17.96
236	Savannakhet	MD	105.5387753	16.90521014	119.40	56.12	23.88	11.22
239	Savannakhet	MD	106.0482031	16.80203855	77.59	36.47	15.52	7.29
240	Savannakhet	MD	105.903366	16.73629488	179.27	84.26	43.03	20.22
241	Savannakhet	MD	105.9771451	16.7500138	266.61	125.31	63.99	30.07
242	Savannakhet	MD	105.840428	16.70979286	143.75	67.56	34.50	16.21
243	Savannakhet	MD	105.7221603	16.68715841	120.34	56.56	24.07	11.31
244	Savannakhet	MD	105.8514243	16.65438366	154.78	72.75	37.15	17.46
245	Savannakhet	MD	105.7520535	16.62205977	101.17	47.55	20.23	9.51
246	Savannakhet	MD	106.1946234	16.60798752	141.10	66.32	33.86	15.92
248	Savannakhet	MD	106.1325041	16.40298666	161.89	76.09	38.85	18.26
251	Savannakhet	MD	106.0700252	16.20905331	130.99	61.57	31.44	14.78
253	Savannakhet	MD	106.0703737	16.17167639	146.46	68.84	35.15	16.52
254	Salavan	EG	106.8970188	16.17531376	373.60	175.59	89.66	42.14
255	Savannakhet	MD	105.9304751	16.13139845	150.28	70.63	36.07	16.95
256	Savannakhet	MD	106.0443457	16.06807003	195.26	91.77	46.86	22.03
257	Salavan	MD	106.7363516	16.04638534	208.83	98.15	50.12	23.56
261	Savannakhet	MD	105.7081025	15.92599133	151.33	71.12	36.32	17.07
262	Savannakhet	MD	105.9160493	15.93410065	184.37	86.66	44.25	20.80
263	Xekong	MD	107.1721529	15.84161209	148.39	69.74	35.61	16.74
264	Salavan	MD	105.7175954	15.85309132	230.19	108.19	55.25	25.97
265	Salavan	MD	105.7372228	15.85246003	171.00	80.37	41.04	19.29
267	Xekong	CF	107.1628302	15.8464021	161.44	75.87	37.13	17.45
268	Salavan	EG	105.7552678	15.83535315	391.64	184.07	93.99	44.18
269	Salavan	MD	106.5682803	15.79041886	204.47	96.10	49.07	23.06
270	Xekong	MD	106.5828133	15.5202811	116.20	54.61	23.24	10.92

271	Xekong	MD	106.6104474	15.48959625	187.33	88.04	44.96	21.13
272	Xekong	MD	106.6362093	15.47034021	121.09	56.91	24.22	11.38
273	Champasak	MD	106.4097909	15.27593136	174.23	81.89	41.82	19.65
276	Champasak	MD	106.5753378	15.21990395	152.04	71.46	36.49	17.15
278	Attapeu	MD	106.4874863	14.94176399	193.03	90.72	46.33	21.77
281	Attapeu	MD	106.4233797	14.7931492	108.02	50.77	21.60	10.15
284	Champasak	MD	106.1530148	14.60577352	157.63	74.08	37.83	17.78
290	Oudomxai	MD	101.8584912	21.12096459	263.89	124.03	63.33	29.77
292	Louangnamtha	MD	101.3289007	20.98960375	140.43	66.00	33.70	15.84
293	Louangnamtha	MD	100.9704854	20.90064347	217.88	102.41	52.29	24.58
295	Louangnamtha	MD	101.282954	20.80527504	153.65	72.22	36.88	17.33
297	Bokeo	MD	100.5661144	20.65281881	197.74	92.94	47.46	22.31
298	Houaphan	MD	103.9949176	20.68357855	87.59	41.17	17.52	8.23
299	Bokeo	MD	100.6390899	20.59413817	166.26	78.14	39.90	18.75
301	Bokeo	MD	100.1709493	20.45866954	195.00	91.65	46.80	22.00
303	Bokeo	MD	100.7110102	20.32748464	164.52	77.33	39.49	18.56
304	Houaphan	MD	104.3663154	20.12449794	174.41	81.97	41.86	19.67
306	Xiengkhouang	MD	103.1970317	19.75275286	231.99	109.03	55.68	26.17
307	Xiengkhouang	MCB	103.1190287	19.55372311	136.69	64.25	32.81	15.42
308	Xiengkhouang	MD	103.1461615	19.54675691	104.39	49.06	20.88	9.81
309	Xiengkhouang	MCB	103.1542629	19.53209956	92.20	43.33	18.44	8.67
310	Xiengkhouang	MCB	103.0832677	19.49819576	53.88	25.32	10.78	5.06
311	Xiengkhouang	MCB	103.2766515	19.4999081	62.53	29.39	12.51	5.88
312	Xiengkhouang	MCB	103.2804491	19.50449866	98.87	46.47	19.77	9.29
313	Xiengkhouang	CF	103.3120828	19.50747265	118.38	55.64	37.88	17.81
314	Xiengkhouang	MD	102.7564535	19.42055516	132.27	62.17	31.75	14.92
315	Xiengkhouang	CF	103.3074322	19.49777721	182.01	85.54	41.86	19.68
316	Xiengkhouang	CF	102.996673	19.39265126	230.40	108.29	52.99	24.91
317	Xiengkhouang	MD	103.2380398	19.3908217	187.64	88.19	45.03	21.17
318	Xiengkhouang	CF	103.471378	19.43596692	183.38	86.19	42.18	19.82
319	Xiengkhouang	MD	103.0003271	19.37771605	146.22	68.72	35.09	16.49
320	Xiengkhouang	CF	103.0285825	19.37595631	125.73	59.09	40.23	18.91
321	Xiengkhouang	MCB	102.9987505	19.32014009	152.24	71.55	36.54	17.17
322	Khammouan	MCB	105.083835	17.87392366	194.43	91.38	46.66	21.93

323	Khammouan	MCB	105.1364835	17.87412558	210.78	99.07	50.59	23.78
324	Khammouan	MCB	105.0772511	17.85932172	142.07	66.77	34.10	16.03
325	Khammouan	MCB	105.1016075	17.86950032	164.87	77.49	39.57	18.60
326	Khammouan	MCB	105.1118471	17.85941463	223.39	104.99	53.61	25.20
327	Khammouan	MCB	105.1436798	17.86870216	177.42	83.39	42.58	20.01
328	Khammouan	MCB	105.1403233	17.82702201	232.57	109.31	55.82	26.23
329	Khammouan	MCB	105.1985454	17.84092528	215.16	101.13	51.64	24.27
330	Khammouan	MCB	105.1606825	17.81280676	158.16	74.33	37.96	17.84
331	Khammouan	MCB	105.1725739	17.80827526	212.66	99.95	51.04	23.99
332	Khammouan	MCB	105.2388995	17.76057841	239.88	112.74	57.57	27.06
333	Khammouan	MCB	105.3459021	17.70053658	275.08	129.29	66.02	31.03
334	Khammouan	MCB	105.3799241	17.7005968	307.74	144.64	73.86	34.71
335	Khammouan	MCB	105.392362	17.69843423	180.37	84.77	43.29	20.35
337	Xekong	EG	107.2422948	15.71466448	264.18	124.16	63.40	29.80
338	Xekong	EG	107.2520416	15.68414974	220.10	103.45	52.82	24.83
339	Xekong	EG	107.255642	15.65689288	364.66	171.39	87.52	41.13
346	Xekong	CF	107.2362644	15.42523967	85.65	40.25	27.41	12.88
347	Xekong	CF	107.1008042	15.40708036	207.62	97.58	47.75	22.44
348	Xekong	CF	107.2275454	15.41801665	94.42	44.38	30.22	14.20
350	Xekong	CF	107.1947865	15.37590886	51.88	24.38	16.60	7.80
352	Xekong	CF	107.1865826	15.36241508	94.12	44.24	30.12	14.16
353	Xekong	MD	107.5970675	15.29586554	195.03	91.66	46.81	22.00
354	Champasak	MD	105.3920586	14.36759616	87.82	41.28	17.56	8.26
355	Champasak	MD	105.4178655	14.34894748	52.41	24.63	10.48	4.93
356	Xiengkhouang	MD	103.1656858	19.82967552	129.41	60.82	31.06	14.60
358	Xaignabouly	MD	101.0740904	19.67108498	123.75	58.16	24.75	11.63
359	Xiengkhouang	MD	103.0585917	19.69767408	137.88	64.80	33.09	15.55
360	Xaignabouly	MD	101.4508341	19.57082015	124.64	58.58	24.93	11.72
364	Xiengkhouang	MD	103.5454961	19.15517727	268.12	126.02	64.35	30.24
366	Xaisomboun	MD	103.5074865	19.0220874	120.29	56.54	24.06	11.31
367	Xaisomboun	MD	102.7307166	18.7050125	155.77	73.21	37.39	17.57
369	Vientiane	MD	101.9334969	18.57198331	62.29	29.28	12.46	5.86
370	Xaisomboun	MD	102.7252544	18.50493064	154.25	72.50	37.02	17.40
371	Bolikhamxai	MD	104.6257971	18.43797311	168.00	78.96	40.32	18.95

373	Vientiane	MD	101.6065724	18.22520776	154.11	72.43	36.99	17.38
374	Vientiane Capital	MD	102.1443268	18.27575042	100.40	47.19	20.08	9.44
375	Vientiane	MD	101.6527459	18.23092983	90.10	42.35	18.02	8.47
376	Bolikhamxai	MD	105.0623567	18.26797935	181.76	85.43	43.62	20.50
377	Vientiane Capital	MD	102.3772111	18.08040263	137.97	64.85	33.11	15.56
378	Vientiane	MD	101.7443708	18.06636688	85.43	40.15	17.09	8.03
379	Vientiane	MD	101.4689822	18.00873761	63.17	29.69	12.63	5.94
382	Khammouan	MD	105.0887544	17.44422003	176.48	82.94	42.35	19.91
384	Savannakhet	MD	105.3419553	17.00117497	112.25	52.76	22.45	10.55
386	Savannakhet	MD	105.2647217	16.47580096	124.61	58.56	24.92	11.71
389	Xekong	MD	107.2066727	15.62738892	161.82	76.05	38.84	18.25
395	Champasak	MD	106.0331109	14.2060711	130.47	61.32	31.31	14.72
396	Champasak	MD	106.0462843	14.14237484	125.30	58.89	30.07	14.13
397	Champasak	MD	106.0584265	14.14982853	116.66	54.83	23.33	10.97
398	Phongsaly	MD	101.8612221	21.67218678	134.75	63.33	32.34	15.20
399	Phongsaly	MD	101.9915691	21.5144126	227.10	106.74	54.51	25.62
403	Louangnamtha	MD	100.9287336	21.05668014	134.57	63.25	32.30	15.18
409	Oudomxai	MD	101.7556866	20.38313089	131.74	61.92	31.62	14.86
411	Houaphan	MD	104.248748	20.27490407	131.12	61.63	31.47	14.79
413	Houaphan	MD	103.459963	20.05534531	186.87	87.83	44.85	21.08
414	Houaphan	MCB	103.9074008	20.06731651	206.31	96.96	49.51	23.27
417	Louangphabang	MD	102.472757	19.64058802	124.67	58.59	24.93	11.72
420	Xiengkhouang	CF	103.1044254	19.39375993	151.82	71.35	34.92	16.41
421	Xaignabouly	MD	101.4958383	19.2569472	175.53	82.50	42.13	19.80
424	Vientiane	MD	102.1527539	19.14281158	141.78	66.64	34.03	15.99
425	Xiengkhouang	MD	103.7883761	19.14826442	311.25	146.29	74.70	35.11
426	Xiengkhouang	MD	103.9004274	19.15518649	324.05	152.30	77.77	36.55
428	Xaisomboun	MD	102.8676417	18.94981675	93.18	43.79	18.64	8.76
429	Xaisomboun	MD	102.8307508	18.88262754	107.44	50.50	21.49	10.10
430	Bolikhamxai	EG	104.1743132	18.82986949	372.53	175.09	89.41	42.02
431	Bolikhamxai	EG	104.1014463	18.63273752	245.91	115.58	59.02	27.74
433	Bolikhamxai	MD	103.9015794	18.60460098	266.92	125.45	64.06	30.11
435	Bolikhamxai	MD	104.3734648	18.62635114	118.87	55.87	23.77	11.17
436	Xaisomboun	MD	103.2575859	18.54780051	202.82	95.32	48.68	22.88

437	Xaisomboun	MD	103.3978084	18.56092016	219.05	102.95	52.57	24.71
438	Bolikhamxai	EG	105.0089033	18.56274951	328.08	154.20	78.74	37.01
440	Bolikhamxai	MD	104.0187643	18.40489091	156.50	73.56	37.56	17.65
441	Bolikhamxai	EG	104.404272	18.40969567	423.33	198.97	101.60	47.75
442	Bolikhamxai	MD	104.4763029	18.34277866	212.70	99.97	51.05	23.99
443	Bolikhamxai	EG	104.5279446	18.28891202	407.07	191.32	97.70	45.92
444	Bolikhamxai	EG	104.5482074	18.22653797	401.38	188.65	96.33	45.28
445	Bolikhamxai	MD	104.3079433	18.17685801	176.62	83.01	42.39	19.92
446	Khammouan	EG	104.5948532	18.19454122	567.89	266.91	136.29	64.06
447	Khammouan	EG	105.1575967	18.06468111	437.17	205.47	104.92	49.31
448	Khammouan	EG	105.2175815	18.01720806	277.67	130.51	66.64	31.32
449	Khammouan	EG	105.1995838	17.93789372	193.97	91.17	46.55	21.88
450	Khammouan	EG	105.1772702	17.90903101	423.89	199.23	101.73	47.82
451	Khammouan	EG	105.2382828	17.90603184	262.53	123.39	63.01	29.61
457	Champasak	MD	105.6329807	14.99279796	67.35	31.65	13.47	6.33
459	Champasak	MD	105.9778235	14.71749397	167.12	78.55	40.11	18.85
460	Champasak	MD	106.0552614	14.71758035	141.02	66.28	33.84	15.91
461	Phongsaly	MD	102.8580526	21.59532672	134.38	63.16	32.25	15.16
462	Phongsaly	MD	102.7945781	21.48514528	126.07	59.25	30.26	14.22
463	Phongsaly	MD	101.8753185	21.32653226	172.45	81.05	41.39	19.45
464	Oudomxai	MD	101.8103282	21.02838948	207.55	97.55	49.81	23.41
465	Louangnamtha	MD	101.0407283	20.91420347	237.40	111.58	56.98	26.78
466	Louangnamtha	MD	100.6628012	20.87231018	164.40	77.27	39.46	18.54
467	Oudomxai	MD	102.0254179	20.8707752	86.61	40.71	17.32	8.14
469	Houaphan	MD	104.0441498	20.7592158	88.82	41.75	17.76	8.35
471	Houaphan	MD	104.3180927	20.67555066	216.30	101.66	51.91	24.40
472	Louangnamtha	MD	101.1514415	20.59967118	212.70	99.97	51.05	23.99
473	Louangnamtha	MD	101.2411216	20.59052572	233.98	109.97	56.16	26.39
475	Bokeo	MD	100.9534962	20.16725795	160.09	75.24	38.42	18.06
476	Bokeo	MD	100.6876234	20.15904759	137.51	64.63	33.00	15.51
477	Louangphabang	MD	102.5428764	20.11793035	90.47	42.52	18.09	8.50
478	Oudomxai	MD	101.5483517	20.05059307	108.49	50.99	21.70	10.20
479	Houaphan	CF	103.8333135	20.19881768	98.79	46.43	31.61	14.86
480	Houaphan	MCB	103.8919303	20.18452435	66.21	31.12	13.24	6.22

482	Salavan	DD	105.9708331	15.74070684	96.76	45.48	19.35	9.10
483	Salavan	MD	106.011648	15.77824017	206.05	96.84	49.45	23.24
484	Champasak	MD	106.4674608	15.25085174	178.40	83.85	42.81	20.12
486	Champasak	MD	106.5682315	15.20385215	132.26	62.16	31.74	14.92
487	Champasak	MD	106.0574967	14.73688664	112.09	52.68	22.42	10.54
488	Champasak	MD	105.9504454	14.70617639	96.95	45.57	19.39	9.11
490	Champasak	MD	106.160818	14.61703896	192.31	90.38	46.15	21.69
492	Houaphan	MD	103.3833683	20.3633989	152.52	71.69	36.61	17.20
493	Savannakhet	MD	106.161986	16.82843987	116.89	54.94	23.38	10.99
494	Savannakhet	MD	106.0607409	16.77038794	217.97	102.44	52.31	24.59
495	Savannakhet	MD	106.0501895	16.66751491	169.54	79.68	40.69	19.12
496	Savannakhet	MD	106.0305799	16.47173096	116.96	54.97	23.39	10.99
497	Savannakhet	MD	105.9908009	16.41687711	133.63	62.81	32.07	15.07
498	Savannakhet	MD	106.3650861	16.41217214	187.75	88.24	45.06	21.18
499	Khammouan	EG	105.7195633	17.606773	365.93	171.99	87.82	41.28
500	Khammouan	EG	105.7632382	17.61697336	342.53	160.99	82.21	38.64
501	Khammouan	EG	105.7682771	17.59038634	250.56	117.76	60.13	28.26
503	Khammouan	EG	106.0834943	17.14207786	289.14	135.90	69.39	32.62
504	Khammouan	EG	106.1666651	17.10276917	216.38	101.70	51.93	24.41
505	Xekong	EG	107.2551533	15.66570666	236.02	110.93	56.64	26.62
511	Xiengkhouang	MD	103.5933816	19.31303496	135.61	63.74	32.55	15.30

Annex 4: QC Survey Plot Information

			NFI sampling				QC sampling				
Plot number	**Province Name**	**Forest class**	**C stock (t/ha)**	**StD**	**StE**	**CI (95%)**	**C stock (t/ha)**	**StD**	**StE**	**CI (95%)**	***p* value**
2	Xiengkhouang	MCB	38.13	35.16	17.58	55.95	50.23	30.89	15.44	49.15	0.632
3	Xiengkhouang	MCB	55.79	9.35	4.67	14.88	53.47	10.69	5.35	17.02	0.632
7	Xiengkhouang	MCB	43.35	14.77	7.38	23.50	41.41	24.48	12.24	38.96	1
8	Xiengkhouang	CF	50.61	18.65	9.32	29.67	45.50	21.70	10.85	34.54	0.446
9	Xiengkhouang	CF	52.20	28.18	14.09	44.85	55.50	26.02	13.01	41.40	0.8
16	Xiengkhouang	MCB	51.75	24.60	12.30	39.14	45.36	19.53	9.77	31.08	0.6
20	Xiengkhouang	MCB	57.30	24.50	12.25	38.98	56.68	16.81	8.40	26.75	1
37	Salavan	CF	48.30	15.65	7.82	24.90	44.42	23.36	11.68	37.17	0.632
38	Salavan	CF	35.10	15.10	7.55	24.04	30.80	15.63	7.82	24.88	0.446
57	Champasak	MD	60.33	18.64	9.32	29.66	64.80	26.66	13.33	42.43	0.489
59	Houaphan	CF	32.02	15.98	7.99	25.42	37.34	12.32	6.16	19.60	1
60	Houaphan	CF	32.36	13.33	6.67	21.22	29.20	10.10	5.05	16.08	0.816
61	Houaphan	CF	78.59	36.63	18.31	58.29	79.24	33.93	16.96	53.98	0.8
111	Salavan	DD	79.19	11.54	5.77	18.36	53.37	15.62	7.81	24.85	0.073
112	Salavan	DD	59.07	12.29	6.14	19.55	56.60	11.68	5.84	18.59	0.8
113	Salavan	DD	59.61	12.97	6.48	20.63	48.21	12.66	6.33	20.14	0.258
114	Salavan	DD	47.20	9.35	4.68	14.88	55.95	16.20	8.10	25.77	0.6
124	Champasak	DD	48.21	19.48	9.74	31.00	55.31	15.26	7.63	24.29	0.489
129	Champasak	MCB	33.04	5.87	2.94	9.34	31.94	7.38	3.69	11.74	0.8
133	Attapeu	DD	41.37	16.09	8.04	25.60	37.74	11.41	5.70	18.15	0.632
134	Attapeu	DD	52.26	10.74	5.37	17.10	50.92	9.67	4.83	15.38	0.632
138	Attapeu	DD	34.89	15.64	7.82	24.89	48.55	23.80	11.90	37.87	0.258
139	Champasak	DD	62.98	22.95	11.48	36.53	67.36	22.94	11.47	36.51	1
142	Champasak	DD	53.47	9.86	4.93	15.69	49.97	2.93	1.46	4.66	1
183	Xaisomboun	MD	179.60	42.44	21.22	67.54	138.36	59.59	29.79	94.82	0.313
264	Salavan	MD	129.03	34.45	17.22	54.82	103.50	19.47	9.73	30.98	0.313
265	Salavan	MD	108.67	17.44	8.72	27.75	105.55	17.23	8.61	27.41	0.8
268	Salavan	EG	228.74	60.21	30.11	95.81	219.00	63.68	31.84	101.32	1
276	Champasak	MD	83.26	18.01	9.00	28.66	98.72	17.87	8.94	28.44	0.446
278	Attapeu	MD	108.57	25.10	12.55	39.94	183.19	54.95	27.48	87.44	0.969
281	Attapeu	MD	56.46	23.38	13.50	58.09	55.91	20.08	11.59	49.88	0.861
292	Louangnamtha	MD	75.29	12.50	6.25	19.89	114.04	39.41	19.71	62.71	0.41
293	Louangnamtha	MD	121.54	33.05	16.53	52.59	155.46	44.18	22.09	70.31	0.313
295	Louangnamtha	MD	83.54	12.26	6.13	19.51	134.36	29.88	14.94	47.54	0.073
354	Champasak	MD	44.27	18.72	9.36	29.79	51.48	28.87	14.43	45.94	0.816
355	Champasak	MD	24.62	4.54	2.27	7.22	37.62	29.18	14.59	46.44	0.816

367	Xaisomboun	MD	84.95	46.76	27.00	116.16	65.72	43.78	21.89	69.67	0.552
370	Xaisomboun	MD	84.24	22.62	11.31	36.00	80.10	33.21	19.18	82.50	0.793
403	Louangnamtha	MD	71.79	48.27	24.14	76.82	94.46	41.54	20.77	66.11	0.632
414	Houaphan	MCB	120.16	27.48	13.74	43.72	127.27	21.18	10.59	33.70	0.632
428	Xaisomboun	MD	48.02	31.97	15.99	50.88	44.86	37.11	18.56	59.06	0.8
429	Xaisomboun	MD	56.00	29.99	14.99	47.72	31.43	18.93	9.46	30.12	0.258
436	Xaisomboun	MD	113.66	35.90	17.95	57.12	132.39	38.22	19.11	60.82	0.446
465	Louangnamtha	MD	132.92	42.92	21.46	68.29	192.24	57.80	28.90	91.97	0.187
466	Louangnamtha	MD	90.37	21.55	10.77	34.28	159.73	84.29	42.15	134.13	0.073
480	Houaphan	MCB	37.71	17.85	8.92	28.40	43.08	25.88	12.94	41.18	0.8
486	Champasak	MD	71.65	36.23	18.11	57.65	105.30	41.37	20.68	65.82	0.258